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Original articles

A STUDY OF THE GROWTH OF AMERICAN UPLAND COTTONS IN THE MALWA TRACT OF MADHYA BHARAT

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(Received for publication on March 25, 1952)

(With 6 Text-Figures)

MALWA is one of the important rainfed cotton growing tracts in the Indian Republic. It lies between 21°-22′ and 26°-52′N and 74°-0′ and 83°-0′ E. The Malwa plateau, a wide tableland with a mean elevation of 1,600 feet above the sea level, consists of 34.637 square miles. It includes the area lying between the Vindhya barrier which forms the northern bank of Nermada valley and a point just south of Gwalior ; its eastern link is marked by a ridge which runs from south to north starting near Bhilsa and its western link marches into the southern districts of Rajasthan. It now includes the districts of Dhar, Ratlam, Jhabua, Mandsaur, Shajapur, Rajgarh, Indore, Dewas and Ujjain in Madhya Bharat, northern portion of Bhopal State and southern parts of Chittor, Kotah and Jhalawar districts of Rajasthan.

The total area under cotton crop in Malwa is nearly ten lac acres and the production is about two and a half lac bales. Though this has been regarded a short staple area, a high quality cotton locally known as *Marwari* (*G. hirsutum*) is also grown either as a pure crop or mixed with *desi* cotton known as Malvi (*G. arboreum* race *bengalense*). The yield per acre of American upland cotton (variety Indore-I) is, however, low as compared to the yields obtained under irrigated conditions in the alluvial soils of the Punjab and Sind. It is about 60 lb. of lint equivalent to about 180 lb. of seed cotton per acre. Even though the yield is low, the quality of lint of American varieties is fairly good, the staple length of Indore-I being 7/8th of an inch capable of spinning 22 to 25 H.S.W.C.

The American upland cotton is grown in this tract under rainfed conditions. No information, however, is available on the physiology of growth of these cottons under these conditions. With a view to determine the causes of low yield, it was decided to undertake a study of the physiology of growth of this cotton under rainfed conditions.

The climatic conditions prevailing in this tract do not appear to be favourable for the vegetative growth of the American Uplands. This can be seen from the meteorological data given in Table I. The cotton crop is generally sown with rains after

the break of the south-west monsoon in the second or the third week of June or later in some years.

TABLE I

Meteorological data of climatic conditions for growth of American Upland cotton

	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.
Mean max. temperature F.	103·8	95·3	82·7	82·1	83·7	88·3	83·1	79·1	78·4
Mean min. temperature F.	76·5	75·3	71·3	70·9	69·5	61·8	52·6	48·2	49·1
Rel. humidity	46·3	73·1	89·8	90·4	88·4	62·3	49·9	53·7	49·1
Mean hours of sunshine	10·01	7·77	2·58	2·64	5·87	8·87	9·17	8·87	8·45
Rainfall (inches)	0·50	5·64	13·43	10·19	8·47	1·85	0·89	0·14	0·18

Once the rainy season sets in, the temperatures go down and the days remain cloudy. The mean hours of sunshine are about 2·5 in July and August. The soil remains saturated with moisture on account of heavy rains in the months of July and August so much so that some of the fields become waterlogged. Thus the cotton plant receives a great set back in its vegetative growth. It may be expected that pre-monsoon sowings with well irrigation would produce better growth as the root system would be better developed during pre-rain period. It was, therefore, considered important to study the effect of sowing date along with spacing and manuring on the growth of the cotton crop.

The black cotton soils can be divided into two main types; (1) shallow soils which are waterlogged during the monsoon and (2) deep soils which are well drained.

TABLE II

Mechanical analysis of the soils

Depth (in ft.)	Waterlogged lands				Well drained lands				
	Clay	Silt	Sand	Cal carb.	Depth in ft.	Clay	Silt	Sand	Cal carb.
	per cent	per cent	per cent	per cent		per cent	per cent	per cent	per cent
½	53	24	23	7·5	1	53	24	23	5·0
1	54	22	23	9·0	2	54	23	23	3·0
1½	55	22	22	10·2	3	55	22	22	4·0
2	52	23	24	11·4	4	57	21	22	4·7
3	49	25	26	13·0	5	55	24	21	7·0
4	46	25	27	15·7	6	48	32	20	9·2

In the first type, *murram* (lime concretions) mixed with stones was found at a depth varying from 1½ to 2 feet from the soil surface while no such *murram* layer was found to be present up to a depth of 6 ft. or more in deep well drained soils. Thus during the rainy months there was water within 1½ ft. of the soil surface on such waterlogged lands and the conditions for growth were, therefore, different on the two soil types. It was necessary to study the effect of different factors singly and in combination on the growth of the crop separately on the two soil types.

Review of Literature

The effect of sowing time on yield has been studied in almost all the cotton growing tracts. Crowther [1935-38] studied its effect on the growth and yield of cotton in Egypt and the Sudan by arranging multifactor experiments so that various inter-relationships between different factors could be studied simultaneously. Earlier sowings (25th February) in Egypt gave higher yield than late sowings while in the Sudan crop August sowings gave highest yields. Dastur and Mukhtar Singh [1942] also found that in the Punjab, June sowings in combination with close spacing gave better yields than May sowings as the former did not suffer as much from '*tirak*' or 'bad' opening of bolls as the May sowings.

The importance of spacing on yield of cotton has been realised ever since Duggar [1899] conducted spacing experiments on cotton. Since then many investigators have studied the effect of spacing on cotton yields. Their results quoted by Colling [1926] indicated that close spacing gave the best results. The main findings of Gregory, Crowther and Lambert [1932], Crowther and Mahmud [1935] and Crowther, Tomforde and Mahmud [1936] were that close spacing increased the yield and this increase was more in the late sown crop than in the early sown crop. 25 cm. between holes and 65 cm. between ridges were also found to be the optimum spacings. Dastur and Mukhtar Singh [1942] also found that close spacing was necessary for the late sown crop while the early sown crop did not generally profit by adopting close spacing. Thus there was an interaction between sowing date and spacing.

Manuring was another factor that has been found to influence the growth of the cotton crop. Fertilizers have been used since 1860 for manuring cotton on soils that are depleted of its nutrients [Brown, 1938]. Considerable literature since the discovery of Liebig on the value of fertilizers has accumulated and that has been summarised by Brown [1938] in his book on cotton. But the effects of the important elements, nitrogen, potassium and phosphorus on the morphological development of the cotton plant were first determined by Crowther [1936] in the Sudan and by Dastur [1946] in the Punjab.

Crowther [1934] found that nitrogen increased the meristematic activity of the plant resulting in an increase in the node and flower production. It also increased the relative growth rate but it was found to produce no effect on net assimilation rate. Water on the other hand increased the growth in extension by elongation of inter-nodes. At the bolling stage the absorption of nitrogen was found to decline on account of suppression in the root growth brought about by a lack of carbohydrate supply. Soil nitrogen was, therefore, of no importance at that stage and it should, therefore, be applied at an early stage. Crowther [1934] also found that application of a higher dose of nitrogen should be accompanied by a heavy watering. He also found a significant correlation between nitrogen content of the leaves of seedlings within two weeks after sowing and the final yield.

Crowther [1937] conducted a number of experiments in Egypt to determine the effects of phosphatic manures on the development and yield of cotton plant but the results obtained did not show any constant response of the phosphatic fertilizers on yield.

Dastur and Mukhtar Singh [1944] in their investigations on '*tirak*' in the Punjab American cottons found that '*tirak*' symptoms developed in the crop on light sandy soil deficient in nitrogen and that they could be remedied by the applications of nitrogen. Nitrogen was found to be the most potent factor on light sandy lands as it increased both the vegetative and reproductive growth. It increased the meristematic activity, flowers, bolls, boll weight and yield when applied to such lands. It was also found to prolong the functional activities of the leaves thus delaying senescence. Nitrogen also increased the net assimilation rate in addition to efficiency index (relative growth rate) but it did not alter the other inherent characters of growth as the general trends with peaks and depressions were not shifted by its application. Late application, contrary to findings of Crowther [1934] in Egypt, was found to be slightly better than an early application. Though application of nitrogen proved so beneficial on light sandy lands, it had no effect on lands that were saline in subsoil.

The beneficial effects of nitrogen on light sandy lands were found to diminish as the sowings were done later. Thus nitrogen starvation in the plant was avoided by cutting down the vegetative growth by late planting so much so that there was little response to nitrogen on the growth of the late sown crop. Another symptom of nitrogen deficiency was the yellow-red leaf disease in Sind American cottons. Dastur and Kanwar Singh [1947] in their investigations on the red leaf distinguished two types of red leaf, viz. green-red and yellow-red. The latter type was caused by a deficiency of nitrogen. The leaves got rapidly depleted of nitrogen on account of quick maturation of the crop and consequently turned yellow and red.

The investigations by Crowther and co-workers [1934-38] in Egypt and the Sudan and by Dastur and co-workers [1939-47] in the Punjab and Sind were conducted under irrigated conditions. No such detailed investigations on the growth of American Uplands under rainfed conditions have been reported from anywhere. This study was, therefore, undertaken on American Uplands grown in the black cotton soils of Malwa. It was decided to study the growth of the crop under different conditions of sowing date, spacing and manuring.

It may be mentioned here that some preliminary experiments on the effect of sowing time and detailed experiments on the effect of manuring on yield had been conducted in this tract. Conventry [1919] in one of his reports has mentioned an experiment on cotton at Ratlam in which cotton was sown with irrigation in the month of May before the break of monsoon in which a yield of 1200 lb. of seed cotton per acre was recorded. Kuber Singh and Wad [1934] conducted replicated trials with pre-rain sowings and rain sowings as separate treatments and they found a significant increase in yield by early sowings. These experiments were conducted without reference to soil types, spacing or manuring. Panse [1945] summarised the manurial experiments conducted at Indore and his main conclusion was that the response to nitrogen was high on rich lands and low on poor lands. There was also an increase in response with the increasing dose of nitrogen. All these experiments were, however, conducted with *desi* cottons sown with rains.

The cotton crop in this tract was sown in rows of 14 to 24 in. apart. No special study has been made regarding optimum spacing for the cotton sown on different dates.

Thus in previous work the experiments on cotton were conducted for a study of single factors and, therefore, no information is available on the interrelation of these factors. In those experiments the effect on yield was only determined and growth studies were not attempted. Mostly *desi* cottons were experimented upon. Thus the need for such an investigation was great.

EXPERIMENTS

All experiments were of a multifactor type designed for study of two or three factors at a time and their interrelationship with one another. In all, 18 experiments were conducted during the period 1944 to 1950, out of which six were laid out on waterlogged lands and 12 on well drained lands. All experiments were conducted at the Institute of Plant Industry, Indore. The details of these experiments are presented in Table III. The layout for each experiment varied according to the number of treatments. Wherever the number of treatments was high, confounding of higher order, interactions was resorted to [Yates, 1937].

As can be seen from Table III, while sowing date was included as a factor for study in nine experiments the effect of spacing was studied in seven experiments. The interaction of sowing date and spacing was studied in five experiments.

The effect of nitrogen was studied in 15 experiments while that of phosphorus singly and in combination with nitrogen in nine experiments.

The effect of potash singly and in combination with nitrogen and phosphorus was studied in six experiments.

TABLE III

Details of experiments

Experiment No.	Year	Soil type	Field No.	Factors studied	Layout	Level of each factor
I	1944	Water logged	32N	Sowing dates, spacings between rows	Split plot 6 blocks	12th May : 1/2 June : 5th July 1½ ft. : 2 ft. : 2½ ft. 9 in. : 18 inches
				Spacing between plants		
II	,,	,,	12	Sowing date, variety, nitrogen	Split plot 6 blocks	25th May : 13th June : 5th July, Indore-1 : Sind Sudhar Control : 40 lb. N.p.a.
III	1945	Well drained	42	Sowing date, nitrogen doses	Split plot	12th June, 29th June Control : 50 lb. N.p.a.
				Nitrogen qualities, variety	4 blocks	Groundnut cake, Am., Sulp. Am. Phos. Indore-1, Buri 107

TABLE III

Details of Experiments

Experiment No.	Year	Soil type	Field No.	Factors studied	Layout	Level of each factor
IV	1945	Well drained	381	Sowing date Nitrogen doses Nitrogen quality Variety	Confounded-cum-split plot 6 blocks	1st June ; 13th June, 29th June; Control ; 33 lb. N ; 66 lb. N.p.a. Groundnut cake ; Am. Sulp. Am. Phos. Indore 1 ; Buri 107
V	,,	,,	40	Spacing per plant B/L ratio Nitrogen	Split plot 6 blocks	$\frac{1}{2}$ sq. ft. ; 1 sq. ft. $1\frac{1}{2}$ sq. ft. 1 : 1 ; 1·2 Control : 33 lb. N ; 66 lb. N.p.a.
VI	,,	Water-logged	32N	Sowing date Spacing per palnt B/L ratio Nitrogen	Confounded 9 blocks	28th May ; 8th June, 29th June $\frac{1}{2}$ sq. ft. ; 1sq. ft. 2 sq. ft. 1 : 1 ; 1 : 2 ; 1 : 4 Control : 33lb. N ; 66 lb. N.p.a.
VII	,,	,,	32E	Sowing date	Randonized 6 blocks	25th May ; 15th June
VIII	1946	Well drained	43	All combinations of N, P and K Spacing per plant Variety	Confounded-cum-split plot 4 blocks	Control : 50 lb. N.p.a Control : 100 lb. P_2O_5p.a Control : 100 lb. K_2O_5p.a $\frac{1}{4}$ sq. ft. ; $\frac{1}{2}$ sq. ft. ; 1 sq. ft. $1\frac{1}{2}$ sq. ft. Indore-1 ; Family 2
IX	,,	,,	38C and F	Sowing date Spacing per plant Variety All combinations of N, P and K	Confounded-cum-split plot 4 blocks	1st June ; 16th June $\frac{1}{2}$ sq. ft. ; 1 sq ft. Indore-1 ; Family 2 Control : 50 lb. N.p.a Control : 100 lb. P_2O_5p.a Control : 100 lb. K_2O p.a
X	,,	Water-logged	32N	Same as in Expt. IX	Confounded-cum-split plot 4 blocks	Same as in Expt. IX
XI	,,	Well drained	7	Nirtogen Variety	Split plot 6 blocks	Control: 20, 40, 60, 80, 100 lb. N.p.a. Indore-1 ; Jarilla
XII	1947	Water-logged	32N	Same as in Expt. X (except sowing dates)	Confounded-cum-split plot 4 blocks	Same as in Expt. X 1st June ; 4th July
XIII	,,	Well drained	40	Variety Nitrogen Phosphorus Potash	Confounded-cum-split plot 4 replications	Indore-1 ; Family 2 Control : 25 lb. N. 50 lb. N ; 75 lb. N.p.a Control ; 25 lb. P_2O_5 ; 50 lb. P_2O_5 ;p.a Control ; 50 lb. K_2O ; 100 lb. K_2O ;p.a
XIV	,,	,,	42N	Variety Quality of manures	Split plot 4 blocks	Indore-1 ; Buri 107 ; X4463 Control ; Am. Sulp., Am. Phos (50 lb. N.p.a.) ; Pot. Chlo. (100 lb. K_2Op.a.) ; Pot. Sulp. (100 lbs. K_2Op.a.)
XV	1948	,,	42N	Same as in Expt. XIII	Confounded-cum-split plot 4 blocks	Same as in Expt. XIII
XVI	,,	,,	42N	Variety Nitrogen Phosphorus	Double split plot 4 blocks	Indore : Buri 107 0, 20, 40, 60. 80, 100 lb. N.p.a 0, 25, 50, lb. P_2O_5p.a
XVII	1949	,,	42S	Nitrogen Phosphorus	Split plot 4 blocks	0, 20, 40, 60, 80, 100 lb. N.p.a 0, 25, 50 lb. P_2O_5p.a
XVIII	1950	,,	43	Same as in Expt. XVII	Split plot 4 blocks	Same as in Expt. XVII

METHODS

The methods used for the measurement of certain characters were those recommended by Hutchinson [1938]. Experimental conditions, material and procedure are given along with the presentation of data under proper headings.

Details of observations

Final height of a random sample of 10 plants per plot was determined in all the experiments at the time of the first picking.

Progressive growth data on height at an interval of a fortnight was collected in Experiments IV, V, VI and XV.

The final dry weights per plant and of all its parts respectively were also determined on a random sample of 10 plants in all plots at the time of the first picking in all the experiments. The dry weights per unit area were also calculated from the spacings adopted.

Progressive dry weight data were collected at an interval of two or three weeks from sowing up to the time of the first picking from Experiments I, V and XV.

From the progressive dry weight data collected, the relative growth rate and the net assimilation rate were derived [Gregory 1926].

The first fruiting node, bud, flower and boll initiation periods, square period and boll period were determined in several experiments by making observation on random samples of plants.

The rates of flowering and bolling during the entire season were determined in Experiment III, V and XV. The number of bolls per plant, boll weight and yields were determined in all the experiments.

The earliness index was calculated by Bartletts' formula (1937), $\frac{a+(a+b)+(a+b+c)+\ldots\ldots\ldots}{n\ \ (a+b+c)\ \ldots\ldots\ldots\ldots\ldots\ldots}$ where n=number of pickings, a=yield of first picking, b=yield of second picking, c=yield of third picking, etc.

It was also determined by determining the percentage of the total crop produce in the first picking.

The fruiting coefficient was determined by dividing the weight of seed cotton by the total final dry weight of plant taken at maturity from sample plants in each sub-plot.

These experiments were mainly conducted on '*Indore I*' variety which has a staple of 7/8 in. and is deemed suitable for 22's-25's warp. It gins 29 per cent and lint gives a blow room loss of 9 per cent. The average yield of this variety varies from 200-250 lb. per acre. The family 2 (Malvi cotton) is purely a short staple one its fibre being 11/16 to 13/16 in. long and is adjudged suitable for 14's-16's warp only. Its ginning percentage is 27 and the lint gives a blow room loss of 10-12 per cent. It gives about 200-250 lb. of seed cotton on average fertility fields. *Buri 107*, a superior quality selection from the acclimatized American cotton in former Central Provinces was also included in some of the experiments. It has a staple length of about 0·99 in., and spins 39's warp. It gins 27·7 per cent. It gives slightly lower yield than *Indore I*. There was no differential behaviour of these varieties on different characters and they are, therefore, not discussed separately. *Sind Sudhar* was included in Experiment II and it did not grow well. It gave very poor yield and was excluded for the calculation of the effects of different factors on growth and yield.

The effect of various factors on the final vegetative structure attained by the crop is discussed first followed by a study of the interrelationships of these factors. Progressive growth made by the crop is studied thereafter. The same sequence is followed for the reproductive growth.

I. The Effect of different factors on vegetative growth

(a) *Main effect of sowing date*

The main effects of sowing date on height and dry weights in all the nine Experiments (I, II, III, IV, VI, VII, IX, X and XII) conducted during the period 1944 to 1947 are given in Table III.

The height of the main stem declined as the sowing date advanced from May to July. Although the growth of the crop in Experiment I showed the same trend, it was suppressed due to excessive rainfall in that year. The trends in height were always in favour of early sowings and the crop sown during the last ten days of May produced maximum average height of 71·6 cm. The crop sown with rains towards the end of June or beginning of July was small and stunted and attained an average height of 41·1 cm. Thus the growth of the crop declined in all the experiments, as the sowing time advanced. The effect of sowing date on height was significant in all the nine experiments (Table IV). There were, however, wide variations in the heights of the plants although the crop was sown during the same period. As for instance the crop sown in last ten days of May attained different heights in different

years (Table IV). The differences as great as those caused by the differences in sowing date are also brought about by the differences in the soil condition or on account of differences in the rainfall conditions in different years.

TABLE IV

The main effect of sowing date on vegetative characters

Experiment No.	Year	Nature of soil	Sowing time: 10th to 20th May	Sowing time: 21st to 31st May	Sowing time: 1st to 10th June	Sowing time: 11th to 20th June	Sowing time: 21st June to 5th July	C.D. 5 per cent
				***Height in cm.**				
I	1944	Water-logged	48·7		39·4		29·6	2·66
II	1944	do.		48·7		29·7	24·4	2·11
VI	1945	do.		78·9	74·0		43·3	6·17
VII	1945	do.		87·3		58·7		9·59
X	1946	do.			58·2	43·5		6·39
XII	1947	do.			81·0		41·0	5·08
III	1945	Well drained				76·7	55·5	4·97
IV	1945	do.			78·7	69·5	52·7	4·96
IX	1946	do.			60·2	51·1		6·09
Mean				*71·6*	*65·2*	*54·9*	*41·1*	
				***Dry weight per plant in gm.**				
I	1944	Water-logged	42·8		40·5		8·0	3·52
II	1944	do.		44·6		21·1	7·6	9·07
VI	1945	do.		78·6	47·2		14·4	8·69
VII	1945	do.		63·3		28·2		32·62
X	1946	do.			15·6	5·7		1·57
XII	1947	do.			55·7		17·3	4·89
III	1945	Well drained				63·0	14·7	6·86
VI	1945	do.			83·7	47·8	19·8	9·24
IX	1946	do.			18·1	12·7		1·10
Mean				*62·2*	*43·5*	*29·8*	*13·6*	

*Significant.

The effect of sowing date on the production of dry matter per plant (Table IV) gave similar results as in the case of height; the dry matter production declined as the sowing date advanced. The days remain cloudy in the monsoon period and as the temperatures are low they appear to retard the production of dry matter on account of low photosynthetic activity.

Main effect of spacing

The effect of spacing on height and dry weight in Experiments I, V, VI, VIII, IX, X and XII is given in Table V.

TABLE V

Main effect of spacing on vegetative characters

Experiment No.	$\frac{1}{4}$ sq. ft.	$\frac{1}{2}$ sq. ft.	1 sq. ft.	$1\frac{1}{2}$ sq. ft.	2 sq. ft.	3 sq. ft.	4 sq. ft.	C.D. 5 per cent
				Height in cm.				
I			39·0	38·1	39·8	39·4	39·3	
V		55·4	56·7	58·7				
VI		70·3	64·3		62·5			6·17
VIII	50·8	50·6	50·5	49·7				
IX		55·3	56·0					
X		52·7	48·9					
XII		61·6	60·4					
				Dry weight per plant in gm.				
I			27·1	28·8	30·7	31·8	33·6	5·23
V		25·5	28·2	30·4				2·32
VI		41·0	48·0		51·2			8·69
VIII	7·0	9·5	10·9	13·2				0·61
IX		13·8	17·0					0·90
X		9·9	11·4					1·32
XII		30·2	42·8					4·80
				Dry weight per square yard in gm.				
I			244	173	147	96	80	38·62
V		457	254	184				32·14
VI		693	432		231			14·98
VIII	250	170	95	80				9·70
IX		248	153					20·89
X		178	102					12·29
XII		539	385					88·38

There was very little effect of spacing on height of the main stem. It is possible that under wider spacing there may have been better growth of secondary branches which may have decreased the extension growth.

The spacing showed, however, considerable effect on the production of dry matter, the dry weight per plant increased as the spacing became wider on account of better growth of the plant under latter conditions. When the production of dry matter was considered on the basis of unit area, the reverse condition was obtained. The compensatory growth due to wider spacing did not cover the loss in the number of plants. This effect of spacing both on dry weight per plant and per unit area, therefore, came out to be significant. The greater production of dry matter per unit area under close spacing further indicated that supply of nutrients was not limited under close spacing and the widely spaced crop did not, therefore, fully utilize the nitrogen and other nutrients available from the soil.

(c) *Main effect of nitrogen*

The effect of manuring with nitrogen on height, and the dry weight obtained in Experiments II, III, IV, V, VI, VIII, IX, X, XI, XII, XIII, XV, XVI, XVII and XVIII are given in Table VI.

TABLE VI

Main effect of nitrogen on vegetative characters

Experiment No.	Doses of nitrogen in lb. per acre											C.D. 5 per cent
	0	20	25	33	40	50	60	66	75	80	100	
						Height in cm.						
II	33·4				35·2							2·11
III	53·0					79·2						4·97
IV	55·0			68·2				77·7				4·97
V	49·7			58·0				63·1				4·03
VI	60·0			67·3				69·8				6·17
VIII	46·6					53·2						3·06
IX	54·4					56·9						2·63
X	47·5					54·0						1·99
XI	42·2	52·4			59·5		61·9			61·5	68·0	9·58
XII	52·5			69·5								3·83
XIII	40·7		54·4			62·7			70·7			3·27
XV	32·5		38·4			45·2			51·9			3·72
XVI	33·2	38·6			43·7		50·7			50·6	54·1	4·31
XVII	31·2	37·4			42·0		48·5			50·4	54·1	1·81
XVIII	31·9	36·0			39·4		43·7			44·4	49·9	2·46

TABLE VI—*contd.*

Main effect of nitrogen on vegetative characters

Experiment No.	Doses of nitrogen in lb. per acre: 0	20	25	33	40	50	60	66	75	80	100	C.D. 5 per cent
					Dry weight per plant in gm.							
II	20·7				28·2							7·59
III	28·7					49·0						6·86
IV	42·5			49·4				59·4				9·24
V	21·7			28·3				34·2				2·31
VI	43·5			46·1				50·7				8·69
VIII	8·1					12·2						1·85
IX	11·6					19·1						0·56
X	8·5					12·8						0·45
XI	10·1	11·2			12·7		14·5			15·3	17·4	1·74
XII	27·2			45·9								4·89
XIII	19·7		30·2			35·5			43·1			2·49
XV	11·8		14·4			21·1			23·9			2·01
XVI	11·2	15·1			18·8		22·5			23·3	26·2	3·03
XVII	7·6	12·1			14·1		16·4			18·4	20·3	1·64
XVIII	9·0	12·1			15·4		18·9			20·2	25·7	2·01

Manuring with nitrogen was found to increase the growth significantly in all the experiments. In Experiment XI, XIII, XV, XVI, XVII, and XVIII where four to six levels of nitrogen were kept as treatments, there was a progressive increase in height as the level of nitrogen increased. There was more than 50 per cent increase in height by the use of higher doses of nitrogen, indicating that the added nitrogen was utilized for extension growth.

Nitrogen increased the dry weight of the plant in all the experiments so much so that the effect of nitrogen came out to be significant in all the experiments. There was a progressive increase in dry weight as the level of nitrogen increased in those experiments where three or more doses of nitrogen were applied.

(d) *Main effect of phosphorus and potash*

The effect of manuring with phosphoric and potassic fertilizers on height and dry weight per plant obtained in Experiments VIII, IX, X, XII, XIII, XV, XVI, XVII and XVIII are given in Table VII.

TABLE VII

Main effect of phosphorus and potash on vegetative characters

Experiment No.	Phosphorus (P_2O_5 in lb. p.a.)					Potash (K_2O in lb. p.a.)			
	0	25	50	100	C.D. 5 per cent	0	25	50	100
				Height					
VIII	50·3			49·5		49·8			49·9
IX	54·0			57·4	2·63	56·2			55·1
X	50·1			51·9		50·7			50·1
XII	60·1		61·9			60·5		61·5	
XIII	55·1	58·1	58·2		2·83	57·0	57·7	56·6	
XV	41·4	42·2	42·3			41·3	42·1	42·5	
XVI	47·5	45·1	45·9						
XVII	42·1	43·9	45·3		2·14				
XVIII	39·4	40·8	42·5						
				Dry weight per plant					
VIII	9·5			10·8		9·8			10·4
IX	13·7			17·1	0·44	14·9			15·9
X	10·2			11·1	0·45	10·6			10·7
XII	34·7		38·4			36·9		36·1	
XIII	30·9	32·7	32·7		2·16	32·6	31·8	33·0	
XV	17·0	17·5	19·0			18·0	17·7	17·9	
XVI	20·3	20·4	20·0						
XVII	14·0	14·8	15·6						
XVIII	15·2	17·4	17·9		2·19				

The results indicated slight increases in height and dry weight per plant by the application of superphosphate. The effect of superphosphate on height and dry weight was, however, significant statistically in three experiments in the case of height and in four experiments in the case of dry weight.

The effect of potash on height was not significant in any experiment while the effect on dry weight was significant in one isolated case. It can, therefore, be concluded that potash produced no effect on vegetative growth of the crop.

Thus these manures did not produce any appreciable effects on the vegetative growth of the crop under rainfed conditions in Malwa. It may be mentioned that almost similar results were obtained on the effect of phosphoric and potassic fertilizers applied in the irrigated tracts of the Punjab [Dastur and Mukhtar Singh,

1943] and in the rainfed tracts of Gujerat [Dastur and Gopani 1952]. There was only an indication of a slight increase in height and dry weight when superphosphate was applied.

Interaction of various factors on vegetative characters

(a) *Interaction of sowing date and nitrogen*

The effect of interaction of sowing date and nitrogen in different experiments on height and dry weight per plant is given in Table VIII.

TABLE VIII

Interaction of sowing dates and nitrogen

Experiment No.	Dose of N in lb. p.a.	Increase in height above unmanured plants				Increase in dry weight above unmanured plants			
		d1 early June	*d2* mid June	*d3* rain sown	C.D. 5 per cent	*d1* early June	*d2* mid June	*d3* rain sown	C.D. 5 per cent
II	40					+14·4	+6·2	+2·4	12·68
III	50		+26·3	+26·4			+28·9	+11·6	9·01
IV	33	+16·3	+14·0	+16·8	8·43	+9·2	+8·0	+3·5	
	66	+29·5	+21·7	+3·4		+19·0	+23·6	+8·1	
VI	33	+5·7	+4·7	+11·5		+2·3	+1·4	+4·1	
	66	+9·6	+8·8	+10·8		+8·1	+6·6	+7·1	
IX	50	+3·2		+1·8		+8·0		+7·0	
X	50	+9·6		+3·4		+6·3		+2·4	1·96
XII	33	+26·9		+7·1	6·88	+31·5		+6·0	6·86

The extension growth of the plants sown on different dates was equally affected by application of nitrogen except in four cases where there was greater increase in height in the earlier sowings and the increase declined as the cotton was sown late. This effect was more on the dry weight where the earlier sowings produced more dry weight by application of nitrogen than the later sowings. Consequently, the interaction DN came out to be significant in four cases out of seven while in the remaining experiments the trends were similar though not significant.

(b) *Interaction of sowing date and spacing*

The effect of sowing date and spacing interaction on height was not significant statistically in any experiment. This interaction on dry weight was, however, significant in four experiments out of five (Table IX).

TABLE IX

Interaction of sowing dates and spacing

Experiment No.		Increase in dry weight per plant per wider spacing				Increase in dry weight per sq. yd. over wider spacing			
		d1 early June	*d2* mid June	*d3* rain sown	C.D. 5 per cent	*d1* early June	*d2* mid June	*d3* rain sown	C.D. 5 per cent
I	Close-medium	—4·0	—1·1	+0·4	5·97	+73	+137	+20	99·45
	Close-wide	—10·1	—1·0	+0·9		+84	+174	+32	
VI	Close-medium	—11·4	—8·8	—0·9	14·77	+499	+160	+123	254·36
	Close-wide	—23·0	—9·0	+1·4		+800	+384	+203	
IX	Close-medium	—3·2		—3·2		+120		+70	34·77
X	Close-medium	—2·9		..	2·20	+100		+52	20·73
XII	Close-medium	—29·2		+3·8	6·86	+112		+195	..

The dry weight per plant increased under each sowing as the spacing became wider and that increase became less and less as the sowing date advanced, so much so that there was practically no increase in the dry weight in the rain sown crop. The increase in dry matter per plant was due to better development of secondary branches under the wide spacing than under close spacing in the early sown crop. This effect was not produced on the late sown crop on account of a general depression in growth that occurred in the rain sowings. When the results were expressed on area basis (Table IX) the reverse happened. There was greater production of dry matter in closer spacing at all dates of sowings and this superiority was more in early sowings than in late sowings except in Experiment XII in which wider spacing with early sowing had made vigorous growth due to drier conditions in the earlier stages of growth.

(c) *Interaction of nitrogen and spacing*

The effect of nitrogen in combination with different spacings on height and dry weight per plant came out to be significant only in isolated cases. Thus the growth of the plant increased almost to the same extent under all spacings on account of the application of nitrogen. When the results of dry weight were studied on area basis (Table X) there was a differential effect of nitrogen and spacing factors with relatively much higher increases in dry weight with closer spacing and the increases were

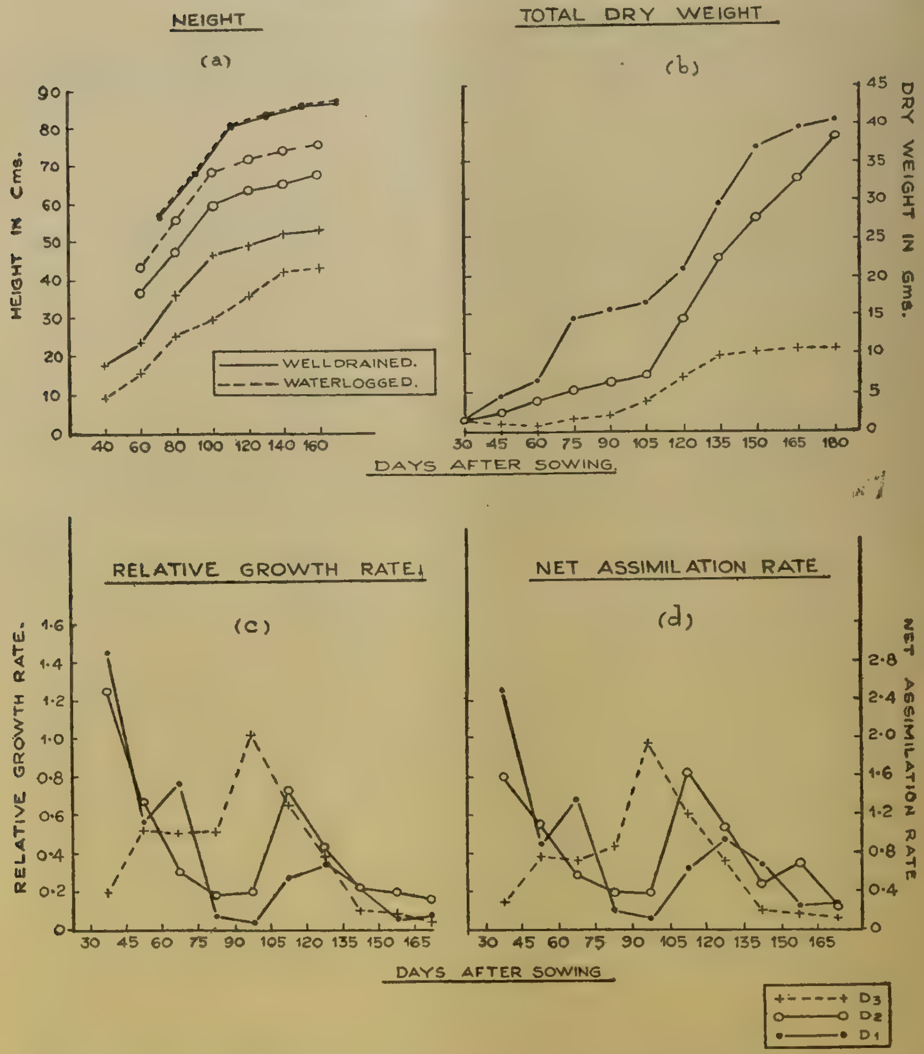

FIG. 1. Effect of sowing date on (a) height ; (b) total dry weight ; (c) relative growth rate ; (d) net assimilation rate. d_1 — 12th May ; d_2 — 1st June ; d_3 — 5th July.

significant statistically in four experiments out of six. The close spacing, therefore, not only produced greater dry weight in absence of nitrogen but also was most responsive to its application.

TABLE X

Increase in dry weight per square yard over unmanured plants

Experiment No.	Increase with N lb. per acre	Very Close	Close	Medium	Wide	C.D. 5 per cent
V	33		+138	+51	+43	
VI	66		+258	+99	+81	53·44
	33		+45		+23	
	66		+13	+80	+21	
VIII	50	+100	+79	+34	+29	14·42
IX	50		+126	+72		29·23
X	50		+78	+40		
XII	33		+221	+221		

Interaction of nitrogen with phosphorus

Phosphorus in combination with nitrogen has a slight enhancing effect on vegetative growth as determined by height and dry weight per plant than when nitrogen alone was applied. As the effect on vegetative growth was slight and it was not significant statistically in majority of the experiments these results are not considered here in details.

THE EFFECT OF DIFFERENT FACTORS ON PROGRESSIVE VEGETATIVE GROWTH

(a) *The effect of sowing date*

The progressive height data was collected at an interval of 20 days in well drained and water-logged fields. The curves for progressive height data of three dates of sowings averaged for all other treatments are given in Fig. 1(a). It will be seen that the cotton plant produced rapid growth in extension during the first 100 days after sowing irrespective of sowing date. The growth in extension was more vigorous in the early sown crop than in the rain sown crop and that was because of a more vigorous root system that develops in the former during the favourable weather condition such as high temperatures and optimum soil conditions that prevail during the pre-monsoon period. A comparsion of the extension growth in two soil types during the same year reveals that there was general lagginess throughout the rainy season in the late sown crop in water-logged fields, otherwise the trends were similar.

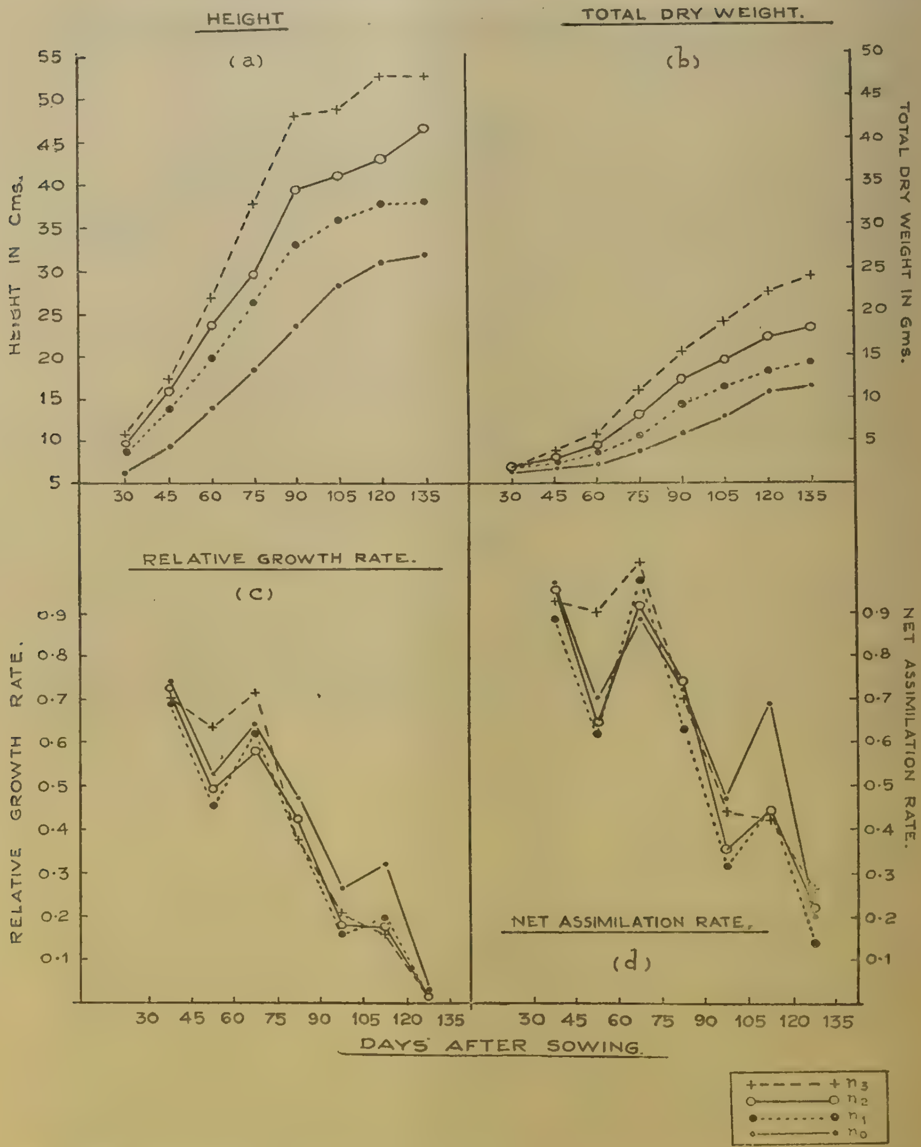

Fig. 2. Effect of nitrogen on (a) height; (b) total dry weight; (c) relative growth rate; (d) net assimilation rate. (n_0 = Control; n_1 = 25 lb.N; n_2 = 50 lb. N; n_3 = 75 lb. N per acre)

The cumulative growth data was collected at fortnightly intervals on total dry matter produced at each stage. The curves for dry matter are given in Fig. 1 (b). The increase in dry matter during the first 100 days after sowing was small after which the crop gained in dry weight at a more rapid rate. This was more rapid in the early pre-rain sowings than in the rain sown crop. Further increase stopped in the rain sown crop 135 days after sowing, while it continued up to the end in the case of early sowings. Thus the plant began to accumulate dry matter when monsoon conditions began to disappear and bright weather returned and this was accompanied by the production of secondary branches. Secondary growth was found to be more vigorous in the pre-rain sown crop than in the rain sown crop.

The relative growth rate and net assimilation rate curves for the different sowing dates are given in Fig. 1 (c and d). As expected the relative growth rate and the net assimilation rate were higher in the pre-rain sown crop than in the rain sown crop during the early stages of growth. Thus the effect of favourable conditions for growth in the early stages of the pre-rain sown crop was visible on the functional activities of the plant. The relative growth rate and the net assimilation rate curves showed secondary peaks during the later stages on account of the return of favourable conditions in September and October. The peak was slightly higher in the rain sown crop than in pre-rain sown crop. Though the number of days after sowing when the secondary peaks appeared, differed in different sowings on account of the differences in the sowing date, the secondary maxima appeared in all cases at the same time.

(b) *The effect of spacing*

There was little effect produced by close, medium or wide spacing on the growth curves except that in the final stages of growth the height and dry weight were higher in the widely spaced crop than in the closely spaced crop. Thus widely spaced crop produced slightly taller and heavier plants and this difference became visible only during the reproductive stage.

(c) *The effect of nitrogen*

The curves for height, and dry weight per plant under different levels of nitrogen are given in Fig. 2 (a and b). The rate of increase in height, however, began to decline 75 to 90 days after sowing. The rate of increase in dry matter was, however, low during the first 60 days after sowing after which it began to increase. The rate of increase was higher in the nitrogen treated plants than in the control plants. Thus nitrogen definitely increased the extension growth as well as the production of dry matter.

The curves showing the relative growth rates and the net assimilation rates are given in Fig. 2 (c and d). The curves for the control plants and the plants treated with 25, 50 and 75 lb. nitrogen are given in the Figure. The curves did not

show any consistent effect of nitrogen on the relative growth rate or the net assimilation rate. There was a depression in the relative growth rate and the net assimilation rate when the rainy weather set in and this depression was more in the plants manured with 25 and 50 lb. nitrogen than even in the control plants. Only in the case of higher doses of nitrogen the depression was not so great and the relative growth rate was higher than in the control plants. It appeared that nitrogen treated plants grow vigorously soon after sowing after which the comparative growth declines giving rise to a decrease in the relative growth rate. The relative growth rate was higher in the untreated plants than in treated plants in the later stages of growth. This was because the rain sown crop became functionally more active after the termination of the monsoon season during which period its activities were suppressed from the beginning owing to adverse weather conditions.

The net assimilation curves given by Dastur and Mukhtar Singh [1943] in the Punjab and by Crowther [1944] for the Sudan showed a steep fall from the very beginning though the actual rate was higher in these tracts than in Malwa. This may be due to the differences in the temperatures prevailing in the Punjab and the Sudan on one side and in Malwa on the other.

THE EFFECT OF DIFFERENT FACTORS ON REPRODUCTIVE GROWTH

(a) *Main effect of sowing date, spacing and nitrogen on the first fruiting node*

The node at which the first fruiting branch appeared was determined on random plants in all the plots of Experiments I, III, IV, VI, VII, IX and X to study the effect of sowing date on the node at which the first fruiting branch appeared. This was necessary in order to determine if the early onset of flowering phase in the early sowing was due to their appearance on lower nodes than in the late sown crops. The observations on the node number at which the first fruiting branch appeared are given in Table XI(a).

TABLE XI(a)

Effect of sowing date on the first fruiting node

Experiment No.	Year	Nature of soil	Sowing time					C.D. 5 per cent
			10th to 20th May	21st to 31st May	1st to 10th June	11th to 20th June	21st June to 5th July	
I	1944	Water-logged	9·0		10·0		11·2	0·80
VI	1945	do.		11·1	10·9		12·1	0·57
X	1945	do.			10·6	10·9		
VII	1946	do.			11·1		13·4	1·43
III	1945	Well drained				9·9	9·3	0·49
IV	1945	do.			9·4	9·4	9·4	
IX	1946	do.			11·1		12·4	0·094

There was in general a lowering effect of early sowing date on the first fruiting node and it was significant statistically particularly in Experiments I, VI, IX and X. In Experiment III alone the effect was reverse and came out to be statistically significant, indicating that in well drained fields (Experiments III and IV) in a year of low rainfall (1945) the first fruiting node was not affected by sowing date.

The effect of spacing on the appearance of the first fruiting node was determined in Experiments I, V, VI, VIII, IX and X but the results are not given here as there was no effect of spacing on the appearance of the first fruiting node.

The effect of nitrogen on the first fruiting node was studied in 11 experiments and the results are given in Table XI(b). There was some effect of nitrogen on the appearance of the first fruiting node. The node at which the first fruiting branch appeared was slightly lower in the manured plants than in the case of unmanured plants.

TABLE XI(b)

Effect of nitrogen on first fruiting node

Experiment No.	Doses of nitrogen											C.D. per cent
	0	20	25	33	40	50	60	66	75	80	100	
III	9·7					9·5						
IV	9·8			9·2				9·2				
V	9·1			8·8				9·1				
VI	11·3			11·5				11·3				
VIII	11·4					10·8						0·44
IX	11·9					11·7						
X	12·7					12·1						
XI	11·3	11·4			10·6		10·8			10·8	10·0	
XV	10·4		9·9			9·0			8·4			0·42
XVII	9·6	8·7			8·1		8·0			8·0	7·6	0·48
XVIII	9·3	7·6			7·7		7·2			7·6	6·8	

Thus the early sowing date and manuring had a slightly lowering effect on the first fruiting node while spacing had no effect. The effect of sowing date on first fruiting node also appeared to be governed by soil and climatic conditions.

(b *Main effect of sowing date, spacing and nitrogen on boll number*

The effect of sowing date on the number of bolls produced per plant was determined in all the nine experiments laid out in different years.

TABLE XII (a)

Effect of sowing date on bolls per plant and bolls per sq. yd.

Experiment No.	Year	Nature of soil	Sowing time					
			10th to 20th May	21st to 31st May	1st to 10th June	11th to 20th June	21st June to 5th July	C.D. 5 per cent
			Bolls per plant					
I	1944	Water-logged	5·66		5·59		1·26	1·30
II	1944	do.		7·19		3·27	0·97	0·54
VI	1945	do.		5·34	5·28		1·68	0·13
VII	1945	do.		5·86		3·87		1·84
X	1946	do.			1·88	0·52		0·37
XII	1947	do.			5·42		2·33	1·02
III	1945	Well drained				3·69	1·98	0·38
IV	1945	do.			5·98	5·04	2·10	0·49
IX	1946	do.			2·59	1·59		0·45
			Bolls per sq. yd.					
I	1944	Water-logged	26·1		26·0		6·3	4·11
II	1944	do.		43·2		23·5	8·7	4·82
VI	1945	do.		44·2	41·0		13·4	4·06
VII	1945	do.		26·8		12·6		6·83
X	1946	do.			24·7	7·1		3·58
XII	1947	do.			44·7	21·3		4·04
III	1945	Well drained				35·0	21·0	2·97
IV	1945	do.			35·4	36·3	22·1	4·07
IX	1946	do.			33·7	20·3		2·36

There was a significant decrease in boll number produced per plant as the sowing date advanced. Early sowings produced significantly greater number of bolls than the later sown crop or the rain sown crop. Thus better vegetative growth produced by the early sowings was accompanied by greater fruiting. The boll production between early and late sowings was also determined on unit area basis (per square yard) as in some of the experiments spacing was included as a separate factor for study. The results of boll number per square yard are given in Table XII(a). The early sowings produced significantly greater number of bolls on unit area basis than the late sown crop in all experiments. In all the experiments the differences between boll numbers per square yard were very large and significant.

The effect of spacing on boll production was determined in seven experiments and the results are given in Table XII(b).

TABLE XII(b)

Effect of spacing on bolls per plant and per square yard

Experiment No.	Spacing per plant						C.D. 5 per cent
	¼ sq. ft.	½ sq. ft.	1 sq. ft.	1½ sq. ft.	2 sq. ft.	3 sq. ft.	
			Bolls per plant				
1			2·72	3·63	4·02	4·42	0·38
V		1·66	2·50	2·91			0·10
VI		2·50	3·59		4·70		0·13
VIII	0·60	1·14	1·57	2·04			0·25
IX		1·83	2·35				0·45
X		1·12	1·29				
XII		2·90	4·84				1·01
			Bolls per square yard				
I			24·5	26·5	20·1	13·3	2·40
V		21·8	18·4	16·0			2·69
VI		45·0	32·4		21·2		4·06
VIII	21·5	20·4	14·2	12·2			3·83
IX		32·9	21·1				2·37
X		20·1	11·7				3·57
XII		37·5	28·5				4·04

There was a significant increase in the bolls produced per plant as the spacing became wider in most of the experiments. Thus wider spacing proved beneficial for reproductive growth when the results were considered on per plant basis. As boll number per unit area was more important from the yield per acre point of view, the results of boll number were calculated on unit area basis for the different spacings in each experiment and are given in Table XII(b). These indicated quite the opposite trends. In this case close spacing produced a significantly larger number

of bolls per unit area than the wider spacing. Thus from the yield point of view close spacing proved superior to wide spacing even though under the latter conditions of growth plants were bigger and produced larger number of bolls individually. But this advantage was offset by the greater plant number per acre under close spacing.

The effect of manuring on the boll number was studied in 16 experiments and the results are given in Table XII(c).

Table XII(c)

Effect of nitrogen on boll number per plant

Experiment No.	Doses of nitrogen											C.D. 5 per cent
	0	20	25	33	40	50	60	66	75	80	100	
II	3·37				4·25							0·49
III	3·21					3·46						0·38
IV	3·41			4·45				5·25				0·47
V	1·58			2·45				3·05				0·10
VI	2·98			3·72				4·10				0·13
VIII	1·03					1·64						0·42
IX	1·63					2·55						0·53
X	0·92					1·48						0·09
XI	1·24	1·68			1·98		2·28			2·44	2·67	0·07
XII	3·45			4·30								0·36
XIII	2·53		3·95			4·67			5·06			0·50
XIV	1·95					4·00						0·48
XV	2·31		3·47			3·68			4·30			0·67
XVI	1·86	3·00			3·21		3·89	3·89		3·84	3·81	0·51
XVII	0·73	1·17			1·47		1·41	1·41		1·72	1·66	0·20
XVIII	3·11	4·54			6·22		6·66	6·66		4·89	7·30	1·22

Manuring significantly increased the boll production per plant. The increase in boll number per plant became greater as the dose of nitrogen increased in those experiments where more than two levels of nitrogen were kept as treatments (Experiments IV, V, VI, XI, XIII, XV, XVI, XVII, and XVIII). Thus early sowing and manuring both increased the vegetative and reproductive growth under Malwa conditions.

The results of bolls produced per square yard with manuring are not given here as the trends in the results were similar to those discussed for the boll number per plant.

(c) *Main effect of sowing date, spacing and manuring on boll weight*

The effect of sowing date on the weight of seed cotton per boll, i.e. boll weight was determined in all the nine experiments and the results are given in Table XIII(a).

TABLE XIII(a)

Effect of sowing date on boll weight

Experiment No.	Year	Nature of soil	Sowing date: 10th to 20th May	21st to 31st May	31st May to 10th June	11th to 21st June	21st June to 5th July (Rain sown)	C.D. 5 per cent
I	1944	Water-logged	1·43		1·89		1·54	0·180
II	1944	do.		2·23		2·22	1·35	0·087
VI	1945	do.		2·64		2·48	2·03	0·114
VII	1945	do.		2·38		2·34		
X	1946	do.			2·10	1·90		0·096
XII	1947	do.			2·15		2·04	0·059
III	1945	Well drained				2·75	2·44	0·099
IV	1945	do.			2·80	2·72	2·55	0·184
IX	1946	do.			2·46	2·22	·	0·100

It was apparent that in the majority of experiments there was a significant decrease in boll weight in the rain sown crop as compared with the boll weights obtained with earlier sowings. In eight experiments out of nine, differences between the boll weights of early and late sown crops came out to be significant. Thus early sowing not only produced greater number of bolls but it also increased the boll size. The contrary was the case in the Punjab and Sind where late sown crop produced bigger bolls than the early sown crop which produced *tirak* symptoms on certain soil types [Dastur, 1944].

There is one more point clear from Table XIII(a) that the boll weight was higher in well drained fields (Experiments III, IV and IX) when compared with the boll weight in water-logged fields (Experiments I, II, VI, X and XII) and this difference was more marked in the rain sowings than in early sowings. The boll weight of very early sowings (12th May in Experiment I) was, however, low.

The effect of spacing on boll weight was studied in seven experiments and it was found that spacing had no effect on boll weight.

The effect of manuring with nitrogenous fertilizers on boll weight was determined in 16 experiments. These results are given in Table XIII(*b*).

TABLE XIII(*b*)

Effect of nitrogen on boll weight

Experiment No.	Doses of nitrogen in lb. p.a.											C. D. 5 per cent
	0	20	25	33	40	50	60	66	75	80	100	
II	1·86				2·01							0·087
III	2·44					2·75						0·087
IV	2·80			2·72				2·55				0·184
V	2·34			2·50				2·67				0·080
VI	2·27			2·40				2·48				0·114
VIII	2·05					2·21						0·074
IX	2·16					2·51						0·034
X	1·86					2·14						0·034
XI	2·03	2·03			2·14		2·27			2·15	2·40	0·131
XII	2·02			2·16								0·043
XIII	2·28		2·42			2·46			2·46			0·064
XIV	2·29					2·56						0·113
XV	2·14		2·31			2·37			2·40			0·067
XVI	2·08	2·32			2·36		2·37			2·45	2·42	0·142
XVII	1·71	1·75			1·78		1·84			1·93	1·92	0·082
XVIII	1·90	2·06			2·15		2·05			2·05	2·18	0·093

Manuring was found to increase significantly the boll weight in almost all the experiments. The boll weight was also found to increase as the dose of nitrogen increased in those experiments where different doses of nitrogen were kept as treatments. Thus early sowing and application of nitrogen increased both boll production and boll weight.

(*d*) *Main effect of phosphatic and potassic fertilizers on the first fruiting node, boll number and boll weight*

The effect of superphosphate on first fruiting node, boll number and boll weight was studied in Experiments VIII, IX, X, XII, XIII, XV, XVI, XVII, and XVIII and that of potash was studied in Experiments VIII, IX, X, XII, XIII and XV and the results are discussed below.

Superphosphate was found to have slightly lowering effect on first fruiting node being significant only in one experiment out of five, while potash did not produce any effect.

Table XIV gives the bolls per plant in the control and manured plants with these fertilizers.

TABLE XIV

Effect of phosphorus and potash on bolls per plant

Experiment No.	Phosphorus 0	Phosphorus 25	Phosphorus 50	Phosphorus 100	C.D. 5 per cent	Potash 0	Potash 25	Potash 50	Potash 100	C.D. 5 per cent
VIII	1·26			1·42		1·33			1·35	
IX	1·83			2·35	0·52	2·03			2·15	
X	1·16			1·25		1·18			1·22	
XII	3·61		4·14			3·82		3·93		
XIII	3·94	4·02	4·20			4·09	3·99	4·07		
XV	3·20	3·45	3·66			3·35	3·38	3·58		
XVI	3·14	3·22	3·44		0·33					
XVII	1·31	1·38	1·38							
XVIII	4·35	6·07	5·94		1·78					

The boll number was found to increase significantly by the application of superphosphate in majority of experiments though the increase in boll number was small in comparison with the increases obtained by the application of nitrogenous fertilizers. Potash was found to produce no such effect on boll production. Thus potassic fertilizers did not affect the boll number of the cotton plant under Malwa conditions.

Superphosphate produced slightly beneficial effect on boll weight but that was small and came out to be significant in four experiments out of nine. Similarly potash also increased the boll weight very slightly but the effect was not significant in any experiment.

(*e*) *Main effect of different factors on fruiting coefficient* (*yield capacity*) *of the plant*

Crowther [1944] used the term fruiting coefficient which was derived by dividing the seed cotton (seed *plus* lint) by the amount of total dry matter produced by the entire plant at the time of the first opening of the bolls. It was necessary to determine if the yield capacity of a crop was its constant feature or it increased or

decreased under the different treatments. The fruiting coefficient, was, therefore, determined in most of the experiments to determine the effect of sowing time, spacing and manuring on this character and to know if any of the agronomical factors increased the efficiency of the crop in the utilization of vegetative growth for crop production.

The effect of sowing date on fruiting coefficient is given in Table XV(*a*)

TABLE XV(*a*)

Effect of sowing date on fruiting coefficient

Experiment No.	Year	Nature of soil	sowing date					C.D. 5 per cent
			10th to 20th May	21st to 31st May	1st to 10th June	11th to 20th June	21st June to 5th July	
I	1944	Water-logged	0·19		0·27		0·25	0·045
II	1944	do.		0·36		0·34	0·17	0·066
VI	1945	do.		0·17		0·25	0·18	0·040
VII	1945	do.		0·23		0·33		0·017
X	1946	do.			0·25	0·17		0·050
XII	1947	do.			0·22		0·30	0·073
III	1945	Well drained				0·17	0·36	0·064
IV	1945	do.			0·21	0·30	0·29	0·023
IX	1946	do.			0·35	0·28		0·027

The fruiting coefficients have varied greatly from experiment to experiment and in different sowing dates. It was as high as 0·36 and as low as 0·17. In some experiments the early sown crop had lower fruiting coefficient than late sown crop and *vice versa*. The effect of sowing date on the fruiting coefficient was, therefore, complex. On closer examination it can, however, be inferred from the data given that in waterlogged fields (Experiments I, II, and VI) or in years of high rainfall (Experiments IX and X) early June sowing gave higher fruiting coefficient than rain sowings. In well drained fields, (Experiments III and IV) and in years of low rainfall, (Experiment XII) however, rain sowings gave higher fruiting coefficient than early sowings. The effect of sowing date on fruiting coefficient was, therefore, governed by soil and climatic conditions.

Table XV (*b*) gives the effect of spacing on fruiting coefficient determined in seven experiments and in all cases the closer spacing gave a lower fruiting coefficient than wider spacing.

TABLE XV(*b*)

Effect of spacing on fruiting coefficient

Experiment No.	¼ sq. ft.	½ sq. ft.	1 sq. ft.	1½ sq. ft.	2 sq. ft.	3 sq. ft.	C.D. 5 per cent
I			0·18	0·24	0·24	0·25	0·063
V		0·16	0·23	0·24			0·026
VI		0·16	0·20		0·23		0·040
VIII	0·17	0·24	0·30	0·32			0·022
IX		0·30	0·32				0·027
X		0·21	0·22				
XII		0·22	0·29				0·073

The effect came out to be significant in five cases out of seven. There was a progressive rise in the value of the fruiting coefficient as the spacing became wider. Thus if more space was available, the efficiency of the plant increased for the production of seed cotton. Wider spacing means greater efficiency while closer spacing gives rise to higher yield per unit area though the efficiency for utilization of the vegetative growth for crop production was lowered.

The effect of different doses of nitrogenous fertilizers on the fruiting coefficient is shown in Table XV(*c*).

TABLE XV(*c*)

Effect of nitrogen on fruiting coefficient

Experiment No.	Doses of nitrogen in lb. per acre											C.D. 5 per cent
	0	20	25	33	40	50	60	66	75	80	100	
II	0·29				0·30							
III	0·26					0·26						
IV	0·24			0·27				0·28				0·023
V	0·17			0·22				0·24				0·026
VI	0·17			0·20				0·22				0·040
VIII	0·24					0·28						0·025
IX	0·30					0·32						0·014
X	0·19					0·24						0·039

TABLE XV (*c*)—*contd.*

Effect of nitrogen on fruiting coefficient

Experiment No.	Doses of nitrogen in lb. per acre											C.D. 5 per cent
	0	20	15	33	40	50	60	66	75	80	100	
XI	0·25	0·29			0·33		0·35			0·34	0·36	0·073
XII	0·27			0·25								
XIII	0·30		0·33			0·33			0·30			0·025
XV	0·43		0·56			0·43			0·44			0·050
XVI	0·36	0·48			0·43		0·45			0·41	0·37	0·077
XVII	0·16	0·18			0·19		0·16			0·19	0·16	0·023
XVIII	0·25	0·20			0·31		0·27			0·19	0·26	0·056

The efficiency of the crop for the production of seed cotton was found to increase on account of application of nitrogen in majority of the experiments. In 14 experiments out of 15 the fruiting coefficient had increased by the application of nitrogen. Thus nitrogen not only increased the vegetative and reproductive growth but also made the crop more efficient in producing seed cotton.

This effect was, however, small in magnitude as can be seen from the results. It is interesting to find from the Experiments XI, XIII, XV, XVII and XVIII that the increase in fruiting coefficient was maintained only up to 66 lb. of nitrogen per acre. Further increase in doses of nitrogen had no effect on the yielding capacity of the plant and the increase in fruiting was not proportional to the increase in vegetative growth. Thus higher doses of nitrogen, i.e. beyond 66 lb. of nitrogen per acre were not utilized economically by the plant, under Malwa conditions.

Phosphatic and potassic fertilizers had practically no effect on the fruiting coefficient as indicated by the results of nine experiments for phosphate and six for potash. The results are, therefore, not given here.

(*f*) *Main effect of different factors on earliness*

The cotton crop in Malwa matures in six months and the boll opening period extends over a period of four months, i.e. November to February. Only three pickings are, however, taken at an interval of 30 to 40 days each. Climatic conditions are not favourable for crop ripening from December onwards due to fall in temperature and in some years the crop is damaged by cold spells. The moisture percentage of the soil during the crop maturing period falls and the quantity and quality of the crop in the latter pickings is, therefore, very poor. The question of earliness has been always in the forefront in the cotton breeding programmes in this tract. Crop earliness at Indore is usually determined by ascertaining the node on

the main stem at which the first sympodium arises. As this character failed to give salient features of the crop maturation it was considered necessary to study the quantitative effect on the actual crop arrival by calculating the percentage of the crop in the first picking to the total and also by determining earliness index.

The effect of sowing date on earliness is given in Table XVI(*a*).

TABLE XVI (*a*)

Effect of sowing date on earliness

Experiment No.	Year	Nature of soil	Sowing date: 21st to 31st May	Sowing date: 1st to 10th June	Sowing date: 11th to 20th June	Sowing date: 21st June to 5th July (rain sown)	C.D. 5 per cent
			Percentage of first picking to total				
VI	1945	Water-logged	90·2	87·4		33·8	1·09
VII	1945	do.	76·5		43·6		19·66
XII	1947	do.		86·4		56·0	7·95
III	1945	Well drained			66·5	41·6	3·81
IV	1945	do.		70·5	65·4	28·4	5·73
			Earliness Index				
VI	1945	Water-logged	0·86	0·81		0·44	0·005
VII	1945	do.	0·90		0·74		0·090
XII	1947	do.		0·77		0·59	0·035
III	1945	Well drained			0·85	0·72	0·023
IV	1945	do.		0·88	0·87	0·69	0·029

It is clear that the percentage of the crop at the time of the first picking in the rain sown crop was very low and significantly lower as compared with the pre-rain sowings. The percentage of the total crop picked in the field in the first picking decreased as the sowing time advanced. The effect on earliness index was also similar to that determined from the percentage of the crop in the first picking. Dastur and Mukhtar Singh [1944], however, had observed in Punjab American cottons that delay in the sowing period did not cause an equivalent delay in the reproductive phase, while Buie [1928] found that early plantings produced plants which required a slightly longer period to start fruiting but produced many more

flowers early in the season. Balls [1912] found that cold surface soil retarded the growth of the early sowing and fruiting phase was delayed and a similar delay was observed if the sowings were delayed too late. In Malwa tract, the rain sowings have also to face the climatic adversities during vegetative growth as well as reproductive growth and the crop arrival is considerably delayed. Thus early sowing in Malwa was the most potent factor in inducing earliness in the plants.

The main effect of spacing on earliness was studied in Experiments V, VI, and XII and the data is given in Table XVI(*b*).

TABLE XVI(*b*)

Effect of spacing on earliness

Experiment No.	Spacing per plant				C.D. 5 per cent
	½ sq. ft.	1 sq. ft.	1½ sq. ft.	2 sq. ft.	
	Percentage of first pickings to total				
V	49·2	45·3	43·8		3·09
VI	70·9	72·7		68·0	
XII	73·0	69·4			
	Earliness Index				
V	0·78	0·75	0·75		
VI	0·70	0·71		0·69	
XII	0·69	0·68			

It is evident that closely spaced crop yielded the highest percentage of the crop in the first picking. There was an increase of 2 to 6 per cent by close spacing in the percentage of crop arrival and an increase of 0·01 to 0·03 in the earliness index. Close spacing is conducive to earlier maturity or at least to more open bolls at an early date. If there are more plants on the ground there is a higher percentage of bolls appearing from the fruiting branches on the main stem. Bolls on these parts develop earlier and the percentage of earlier crop is higher. Similar results were obtained by Ludwig [1931] and Crowther [1937]. They also got a slight increase in the crop arrival under close spacing.

The effect of nitrogen on earliness is given in Table XVI(*c*) separately for (i) percentage of the crop arrival and (ii) earliness index.

TABLE XVI(*c*)

Effect of nitrogen on earliness

Experiment No.	Doses of nitrogen in lb per acre.											C.D 5 per cent
	0	20	25	33	40	50	60	66	75	80	100	
	Percentage of first pickings to total											
III	50·6					57·5						3·81
IV	51·0			56·1				57·2				5·72
V	36·0			49·6				52·6				3·08
VI	67·6			72·7				71·2				1·09
XII	71·0			71·4								
XIII	38·4		45·3			44·7			42·5			7·23
XV	49·4		58·8			61·1			60·8			2·04
XVI	45·6	54·4			60·9		58·2			60·6	57·2	4·88
XVII	51·9	61·0			63·5		66·5			67·9	67·1	1·92
XVIII	48·7	56·5			57·2		50·4			48·2	53·2	3·25
	Earliness Index											
III	0·76					0·81						0·023
IV	0·79			0·82				0·83				0·029
V	0·70			0·78				0·80				0·020
VI	0·69			0·71				0·70				0·006
XII	0·67			0·69								0·035
XIII	0·73		0·77			0·77			0·77			0·030
XV	0·63		0·68			0·72			0·71			0·017
XVI	0·61	0·67			0·71		0·71			0·73	0·71	0·026
XVII	0·80	0·83			0·84		0·85			0·85	0·85	0·025
XVIII	0·81	0·83			0·83		0·81			0·80	0·82	0·028

The lower doses of nitrogen hastened maturity but the higher doses did not further hasten it. It is seen that nitrogenous fertilizer hastened the vegetative and reproductive growth. Thus it was in the early pickings that the bulk of the extra crop from manuring was expected. The plant gets depleted earlier due to vigorous vegetative and reproductive growth and, therefore, the last picking is light. The effect was quite opposite to that reported by Dastur and Mukhtar Singh [1944] in the Punjab. They found that nitrogen delayed the maturity of the crop. The findings here were, however, in general agreement with that of Colling [1926] and Buie [1928]. Colling [1926] found that though application of smaller doses of nitrogen hastened maturity, larger doses of nitrogen delayed it.

The value of phosphatic manuring was usually stated to be one hastening maturation. The percentage of first picking and earliness index was, therefore, determined and it was found that there were slight differences in earliness between control and treated plants. There was also no effect of potash on crop maturity.

(g) *Effect of nitrogen on initiation of bud, flower and opening of boll*

Various observations on the crop to study the effect of the application of sulphate of ammonia on the arrival of the crop were recorded. It was first necessary to determine the days after sowing taken for the (i) first appearance of buds; (ii) first appearance of flowers and (iii) first appearance of bolls. These observations were recorded on one randomised row of plants in all the control plots and in plots receiving different doses of nitrogen. The Table XVII gives the number of days taken after sowing for the first appearance of buds, flowers and bolls in the control and manured plots.

TABLE XVII

Effect of manuring on the initiation of buds, flowers and the appearance of first open boll

Control	Appearance days after sowing		
	First bud	First flower	First open boll
	45	74	128
25 lb. nitrogen	35	68	121
50 lb. nitrogen	35	68	120
75 lb. nitrogen	35	68	112

The bud initiation occurred in the manured plants 10 days earlier than in the control plants, there being no difference under different doses of nitrogen. Even 75 lb. nitrogen made the bud initiation early by only 10 days. Similarly, the first flower appeared six days earlier in the manured plants than in the control plants. The first open boll also appeared eight days earlier in the manured plants than in the control plants. Thus the reproductive phase set in a week to ten days earlier in the crops manured with ammonium sulphate.

(h) *Effect of nitrogen on other fruiting characters*

In addition to the effect of nitrogen on fruiting characters that has been already discussed its effect on number of vegetative branches, fruiting branches, fruiting nodes, bolls set and setting percentage was examined in Experiments XVII and XVIII. The data is presented in Table XVIII.

TABLE XVIII

Effect of nitrogen on fruiting habit

Nitrogen	Vegetative branches 1950	Fruiting branches		Fruiting nodes		Bolls set		Setting percentage	
		1949	1950	1949	1950	1949	1950	1949	1950
n0	0·03	8·0	11·8	14·9	21·5	1·66	1·58	11·2	7·3
n1	0·04	11·0	12·9	20·6	25·2	2·32	2·51	11·3	9·9
n2	0·17	12·0	13·5	24·3	27·6	2·81	2·92	11·2	10·6
n3	0·17	13·0	15·0	28·6	32·1	3·02	3·58	10·6	11·1
n4	0·12	13·5	14·8	29·9	32·5	3·26	4·11	10·9	12·7
n5	0·27	14·4	16·4	34·2	37·4	3·48	4·61	10·2	12·3

It is clear from the Table XVIII that cotton plant under rainfed condition in Malwa bears very few vegetative branches and the growth is mainly sympodial. Nitrogen slightly increases the number of vegetative branches. It increases the number of fruiting branches, number of fruiting nodes and the bolls borne on them. In 1949, application of nitrogen did not affect the setting percentage while it brought about an increase in 1950. It is, therefore, probable that seasonal factors are involved under certain conditions and application of nitrogen may give rise to an increase in setting percentage of bolls in some years.

(i) *Effect of nitrogen on distribution of bolls on the main stem*

The distribution of the crop on the main stem was studied in Experiment XVII and the results are presented in Table XIX.

TABLE XIX

Effect of nitrogen on distribution of bolls on the main stem

	Distribution of bolls on the main stem							Percentage distribution on the main stem					
	A 1-5	B 6-10	C 11-15	D 16-20	E 21-25	F 26-30	Total	A 1-5	B 6-10	C 11-15	D 16-20	E 21-25	F 26-30
n0	..	0·46	0·73	0·41	0·06	..	1·66	..	28·3	44·0	24·0	3·7	..
n1	..	0·74	0·92	0·54	0·12	..	2·32	..	30·2	39·7	23·3	5·2	..
n2	..	0·99	1·07	0·61	0·14	..	2·81	..	35·2	38·8	21·7	5·0	..
n3	..	0·96	1·18	0·65	0·22	0·01	3·02	..	31·8	39·7	21·5	7·2	0·3
n4	..	1·15	1·18	0·67	0·25	0·01	3·26	..	35·3	36·2	20·6	7·7	0·3
n5	..	1·13	1·23	0·82	0·27	0·03	3·48	..	32·8	35·3	23·6	7·8	0·9

The first fruiting branch usually appeared on the 9th-10th main stem node. The frequency of these branches and the distribution of the crop along them were the factors which determine the earliness of the crop. As the maturation period

of the crop was unaffected by the application of nitrogen the order of the production of the bolls determined the order of their opening. To simplify the study of the distribution of the crop the main stem was divided into zones, each zone consisting of five nodes; zone A representing nodes 1-5, zone B nodes 6-10 and so on. Zone A was the lowest zone and generally did not bear fruiting branches and zones E and F were the latest formed and these two zones also were conspicuous for late growth and poor fruiting. Zones B, C and D were responsible for producing about 30, 40, and 20 per cent of the crop respectively.

The effect of nitrogen on actual distribution of the bolls on the main stem in each of the above zones and their percentage distribution are given in Table XIX. An examination of this Table shows that nitrogen increased the boll number equally in all the zones while it did not affect the percentage distribution of the bolls. This was contrary to the results on crop arrival and can be explained on the basis of hastening effect produced by nitrogen on node production and early onset of flowering and bolling in the lower zones. The effect of nitrogen on crop arrival was therefore, indirect. It hastened the vegetative growth in the early stages of plant development and produced a corresponding hastening effect on fruiting.

Interaction of different factors on Fruiting characters

(a) *Effect on first fruiting node*

There was no interaction between any two factors on first fruiting node in an experiment.

(b) *Effect on boll number*

The interaction of nitrogen with sowing date was significant in four experiments out of seven conducted during different seasons (Table XX).

Table XX

Interaction: Sowing date and nitrogen

Experiment No.	Dose of nitrogen p.a.	d1 Early June	d2 Mid June	d3 Rain sown	C.D. 5 per cent
II	40	+1·23	+0·92	+0·50	0·72*
III	50		+1·12	+1·38	0·54*
IV	33	+1·22	+1·23	+0·67	0·83*
IV	66	+2·40	+2·02	+1·10	0·20*
VI	33	+0·73	+0·90	+0·58	
VI	66	+0·95	+1·48	+0·92	
IX	50	+1·02		+0·81	0·64
X	50	+0·86		+0·27	0·43
XII	50	+0·90		+0·78	1·73

*Significant.

All the experiments (except Experiment III) showed similar trends ; the increase in number of bolls per plant produced by nitrogen was lower in the rain sowing than in the pre-rain sowings with one exception. Thus the earlier sowings generally profitted more by application of nitrogen than late sowings in addition to the beneficial effect of early sowing alone on boll production. This suggests that where the mean was higher, the increase in number of bolls with added nitrogen was greatest subject to the law of diminishing returns.

Reference has already been made that early sowings always increase the boll number and close spacing increases the boll number when considered on unit area basis. The results of sowing date and spacing interaction on number of bolls per plant and per square yard are given in Table XXI.

TABLE XXI

Interaction : Sowing date and spacing

Experiment No.	Increase with spacing	Increase in bolls per plant			C.D. 5 per cent	Increase in bolls per sq. yd.			
		d1 Early June	d2 Mid June	d3 Rain sown		d1 Early June	d2 Mid June	d3 Rain sown	C.D. 5 per cent
I	Close-medium	—1·84	—1·78	—0·11	2·21	+0·60	+0·2	+2·3	
	Close-wide	—3·31	—1·89	—0·06		—0·2	+6·8	+3·7	
VI	Close-medium	—1·01	—2·23	—0·03	0·20	+21·7	+5·3	+11·3	6·89
	Close-wide	—3·64	—3·06	+0·10		+29·4	+24·4	+17·7	
IX	Close-medium	—0·52		—0·52		+16·3		+7·3	3·31
X	Close-medium	—0·35		+0·01		+12·1		+4·8	5·02
XII	Close-medium	—3·69		—0·19	1·39	+5·1		+13·1	

This interaction was significant in three experiments out of five while in all the experiments there was greater increase in boll number per plant with wider spacing which decreased with delay in sowing date. The individual plant of early sowing is, therefore, benefitted more by wider spacing than later sown. On unit area basis, however, there was greater increase in boll number with closer spacing and early sowing in three experiments out of five.

The effect of spacing in relation to nitrogen on boll number per plant and per square yard was studied in six experiments and the results are given in Table XXII.

TABLE XXII

Interaction : Spacing and nitrogen

Experiment No.	Dose of N p.a.	Increase in bolls per plant over unmanured plants					Increase in bolls per sq. yd. over unmanured plants				
		Very close	Close	Medium	Wide	C.D. 5 per cent	Very close	Close	Medium	Wide	C.D. 5 per cent
V	33		+0·67	+0·82	+1·10	0·174		+8·9	+6·1	+5·6	4·57
	66		+1·20	+1·43	+1·76			+15·0	+13·3	+9·0	
VI	33		+0·73	+1·38	+0·16	0·229		+12·0	+12·4	+0·7	6·88
	66		+1·36	+1·14	+0·84			+24·4	+10·3	+3·7	
VIII	50	+0·23	+0·63	+0·72	+0·85		+8·4	+11·4	+6·5	+5·1	
IX	50		+0·79		+1·05			+14·2		+9·4	2·77
X	50		+0·49		+0·64			+8·8		+5·9	
XII	33		+0·81		+0·87			+8·6		+5·7	

The increase in boll number per plant due to nitrogen was higher in wide spacing in five experiments out of six. The reverse was the case when considered on area basis and the number of bolls decreased with increase in spacing. The increase in boll number per plant was, therefore, not able to compensate for the greater number of plants per unit area. Close spacing, therefore, gave larger increase in boll number with manuring than wider spacing and was consistantly superior irrespective of other treatments. In the present case, therefore, a close spacing of $\frac{1}{2}$ sq. ft. not only gave higher boll number but also gave consistantly larger response to nitrogen.

The boll number was definitely more in case of nitrogen in combination with phosphorus than that of nitrogen and phosphorus alone. The nitrogen and phosphorus interaction was, however, non-significant in most of the experiments.

(c) *Effect on boll weight*

The effect of nitrogen in combination with sowing date on boll weight was studied in seven experiments. It was found that this interaction, unlike in Punjab, was not significant in any experiment. The early and late sowings were, therefore, equally profitted in boll weight by application of nitrogen.

The effect of sowing date, in combination with spacing, on boll weight was studied in five experiments. This interaction was significant only in two experiments out of five.

The effect of nitrogen, in combination with spacing, on boll weight was studied in six experiments and it was found that this interaction was not significant in any experiment so far as boll weight was concerned. The increase produced by nitrogen in boll weight in the different spacing was, therefore, nearly the same.

There was no significant increase in boll weight by the application of nitrogen in combination with phosphate in any one trial. A close study of the actual increases, however, indicated slightly better effect in favour of their combination rather than phosphate or nitrogen alone.

(d) *Effect on fruiting coefficient and earliness*

The effect of sowing date and nitrogen, sowing date and spacing, nitrogen and spacing and nitrogen and phosphorus interactions on fruiting coefficient was not significant in any experiment.

There was an indication of slightly greater increase in fruiting coefficient by nitrogen application with late (rain) sowings than with early sowings (pre-rain). Similarly, there was greater benefit derived with wider spacing by early sowings than by late sowings. There was no effect of nitrogen with spacing and nitrogen with phosphorus combinations as there was nearly the same increase in the fruiting coefficient.

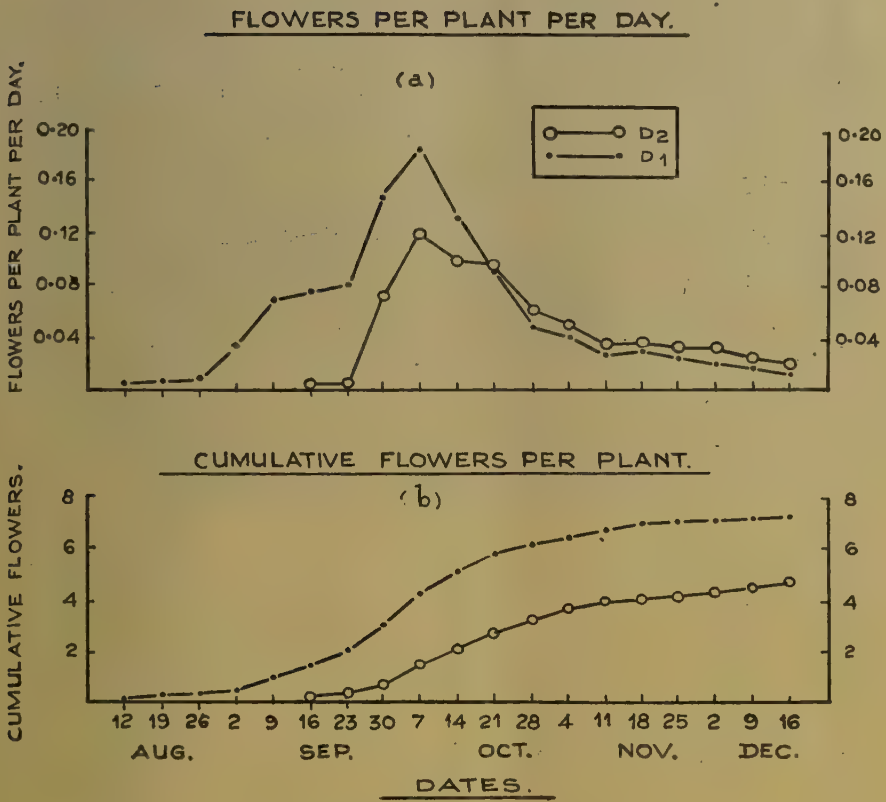

Fig. 3. Effect of sowing date on flowering
(d_1 — 12th June ; d_2 — 29th June)

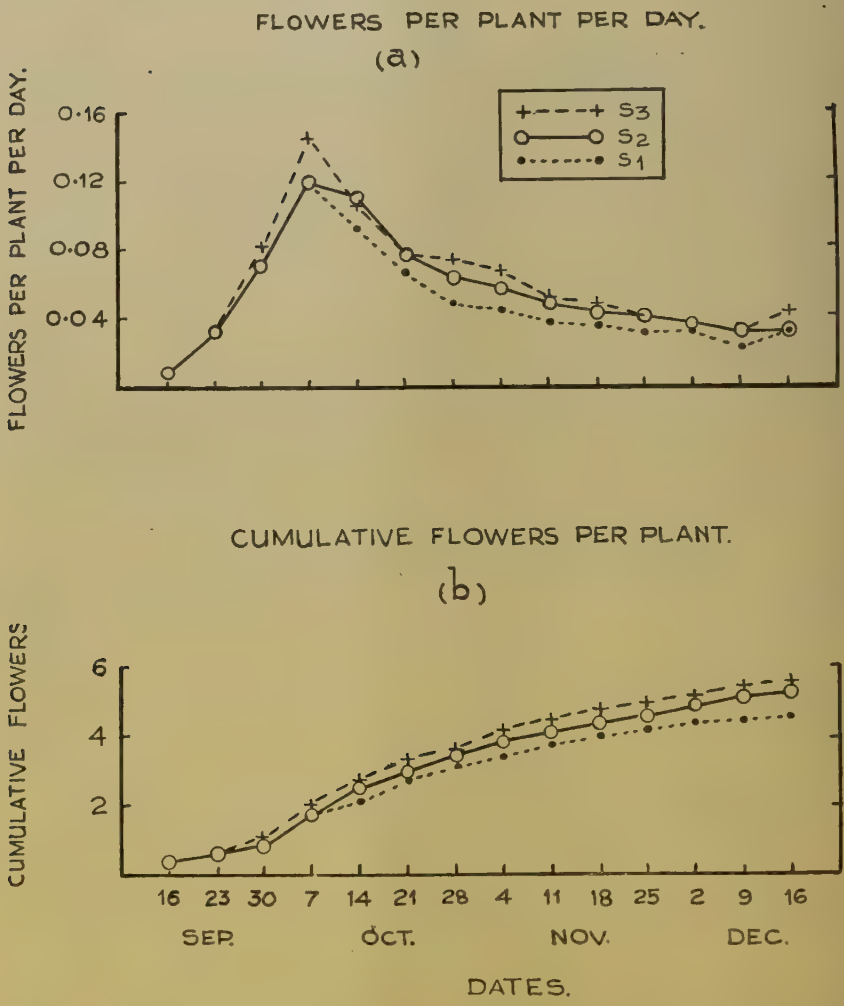

Fig. 4. Effect of spacing on flowering
(s_1 — $\frac{1}{2}$ sq. ft. ; s_3 — sp. ft. ; s_2 — $1\frac{1}{2}$ sq. ft.)

The effect of various interactions on percentage of first picking to total and earliness index did not come out to be significant in any experiment. There was no indication of even a slight differential behaviour.

Effect of different factors on Flowering and Bolling

(a) *The effect of sowing date on flowering*

Fig. 3(a) gives the effect of sowing date on the flowering phase. The flowering started in the middle of August in the early sown while it commenced by the middle of September in the rain sown crop planted on 29th June. The rate of flowering was higher in the early sown crop than in the rain sown crop up to the middle of October when the rates of flowering almost became equal. The flowering rate became slightly higher later on in the late sown crop than in the early sown crop. The peak in flowering was reached in the beginning of October in both sowings. Thus early sowings made the crop early and increased the flowering rate of the crop in the first half of the flowering period. This brought about an early maturation of the crop in the early sowing. This finding was not in agreement with that obtained in the Punjab where crops sown at different dates flowered and fruited almost at the same time. The difference of one month in sowing date in the Punjab made a difference of one week in the onset of flowering phase.

Fig. 3(b) gives the cumulative flower production per plant. The total number of flowers produced per plant was higher in the early sown crop than in the late (rain) sown crop from the very beginning of the flowering phase upto the end.

(b) *Effect of spacing on flowering*

Fig. 4(a) shows the effect of spacing on the rate of flowering and on the commencement and completion of the flowering phase. The flowering commenced and terminated at the same time in all spacings. The early maturity in the closely spaced crop was, therefore, not found to be associated with early initiation of the fruiting phase. This was found to be the case by Hall and Armstrong [1920] and Buie [1928]. The peak in flowering was also reached at the same date, viz. 7th October after which there was a gradual fall in the flowering activity. In the wide spacing (*s3*) a slightly higher rate in the flowering activity was visible at the peak period and it remained at a higher level up to the end than in the case of close spacing. Thus wide spacing increased the flowering to a small extent, very probably on account of better illumination that plants received under wide spacing than under close spacing.

The cumulative flowers produced per plant are given in Fig. 4(b). It will be seen that more flowers per plant are produced under wider spacing than under closer spacing.

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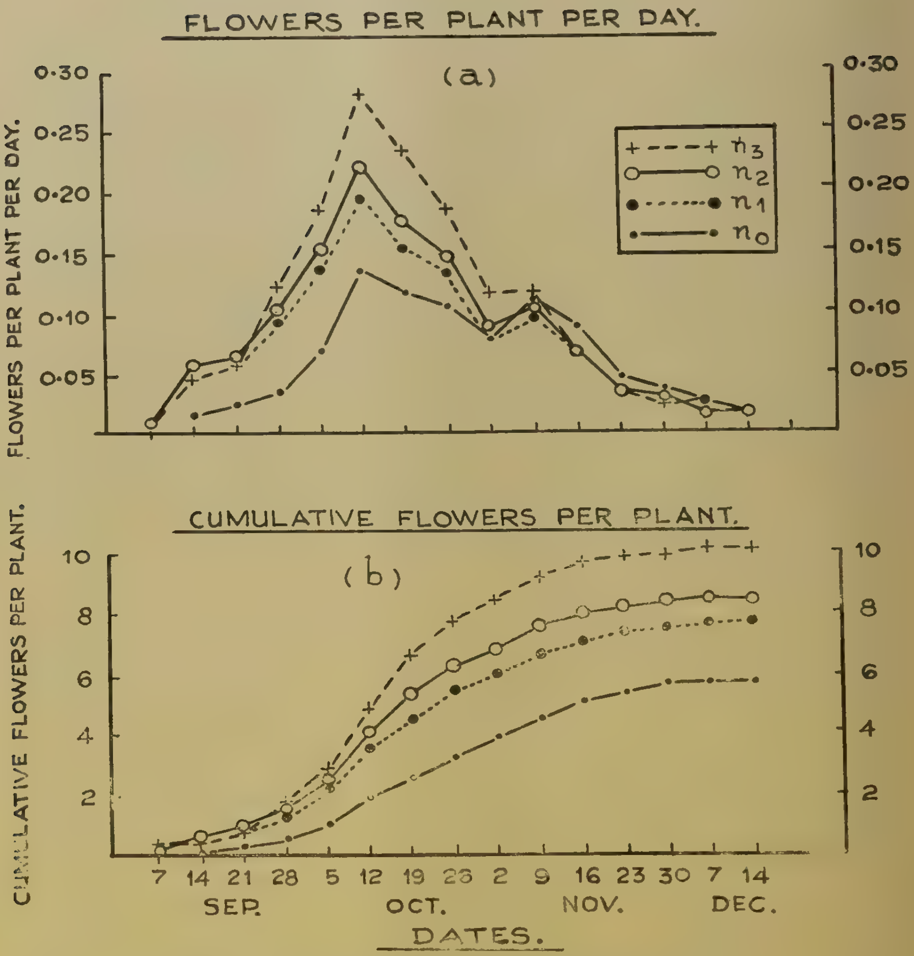

FIG. 5. Effect of nitrogen on flowering
(n_0 — Control ; n_1 — 25 lb. N ; n_2 — 50 lb. N ; n_3 — 75 lb. N. per acre)

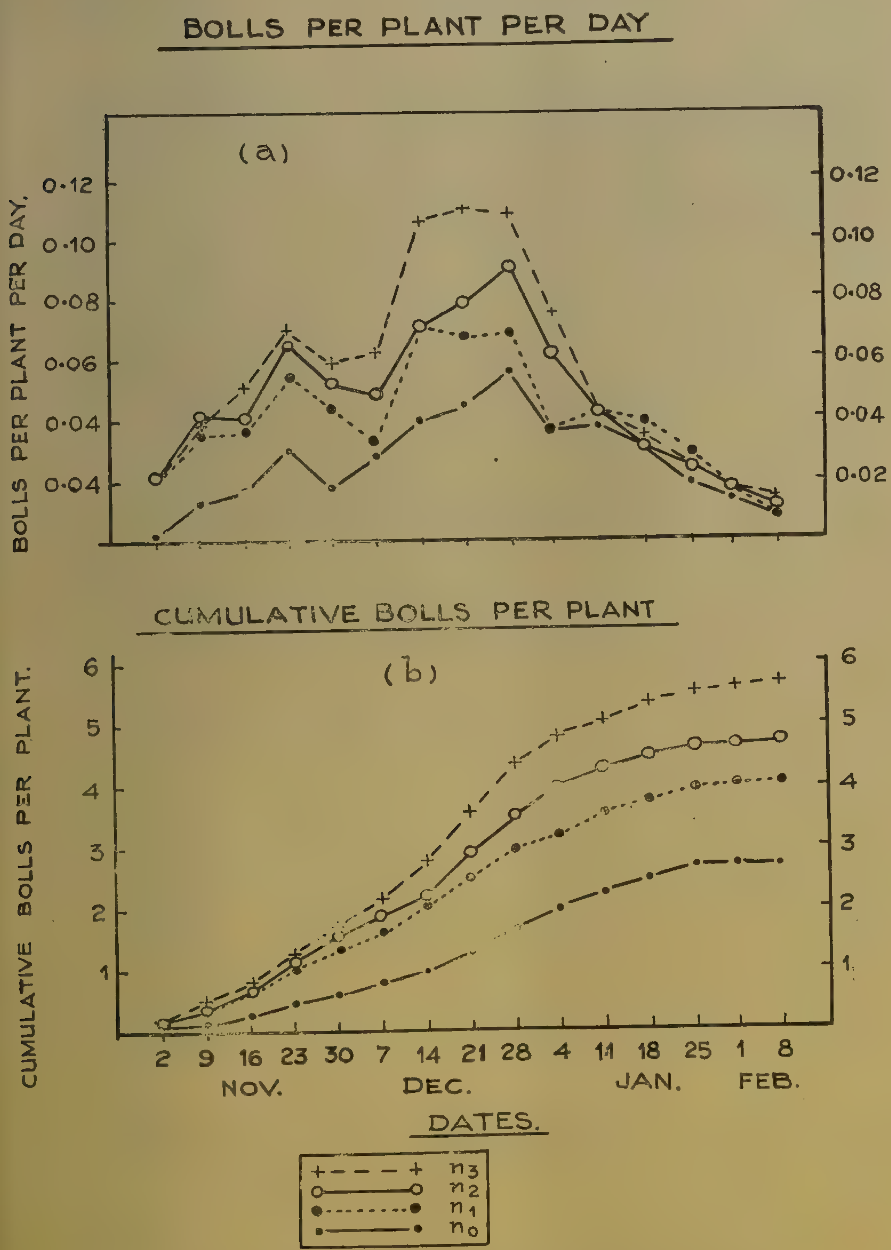

FIG. 6. Effect of nitrogen on boll production
(n_0 — Control; n_1 — 25 lb. N; n_2 — 50 lb. N; n_3 — 75 lb. N. per acre)

(c) *Effect of nitrogenous manuring on flowering*

Fig. 5(a) gives the average flowers per plant, per day (F.P.D.) under four nitrogen treatments. The effect of nitrogenous manuring was almost similar to that produced by early sowings. By application of nitrogen the flowering phase was set in early. The flowering began by 16th September, i.e. a week earlier than in the case of unmanured crop. The flower production like the dry weight rose steeply in plants treated with nitrogen while the increase was gradual in the control plants. The rate of flowering during the early stages of flowering increased as the dose of nitrogen increased. The peak in flowering was reached a little earlier in the manured crop than in the unmanured crop and the peak in the flowering curve stood higher in the manured plants than in the unmanured plants. Thus application of nitrogen made the crop slightly earlier and gave rise to early maturity of the bolls in the manured crop. This finding was in contrast with the finding in the Punjab where application of ammonium sulphate made the crop late. There was no early onset of flowering phase in the manured plants in the Punjab.

Fig. 5 (b) shows the cumulative flower production during the flowering season under four different treatments. The flowering started early in September and flower production became rapid early in October. The flower formation declined in November and ceased in December. Manuring increased the total production of flowers per plant. The higher the dose of nitrogen the greater was the flower production per plant. The total number of flowers produced per plant was about 5·8 in the case of untreated plants while it was 10 in plants manured with maximum dose of nitrogen.

(d) *Effect of nitrogen on boll production*

Fig. 6(a) shows the average number of bolls per plant per day (B.P.D.) during the fruiting season under four different treatments. The opened bolls were alone counted. The curves clearly indicated early opening of bolls in the manured plants. The boll opening increased in November and reached its maximum in the month of December after which the production declined rapidly in the nitrogen treated plants. The peak in boll production reached two weeks later in the control plants. The boll production was greatly increased by the application of nitrogen. It was maximum with 50 lb. N. The graphs clearly indicated early maturity in the manured plants and this was borne out by the determinations of the percentage of total crop picked in the first picking as shown later.

Nitrogen also increased boll production per plant as shown in Fig. 6(b). As in the case of flower production the greater the dose of nitrogen the greater was the number of bolls produced per plant.

THE EFFECT OF DIFFERENT FACTORS ON YIELDS

(a) *Effect of sowing dates on yield*

The mean yields under different sowing dates (averaged over all other treatments) are given in Table XXIII.

TABLE XXIII

Main effect of sowing date on yield

(*Seed cotton in maunds per acre*)

Experiment No.	Year	Nature of soil	Sowing time					
			10th to 20th May	21st to 31st May	1st to 10th June	11th to 20th June	21st June to 5th July (Rain sown)	C.D. 5 per cent
I	1944	Waterlogged	3·81		5·32		0·57	0·85
II	1944	do.		7·04		5·37	0·39	1·74
VI	1945	do.		12·11	10·45		0·99	1·17
VII	1945	do.		8·29		3·82		2·79
X	1946	do.			2·75	0·47		0·67
XII	1947	do.			12·25		4·86	0·69
III	1945	Well drained				12·6	6·8	1·13
IV	1945	do.			12·9	12·7	7·3	1·27
IX	1946	do.			5·91	2·87		0·53

The rain sown crops on waterlogged soils gave very low yields in majority of experiments, the magnitude of yield being in the neighbourhood of one maund per acre. In 1947 (Experiment XII), however, the level of yield was high on such a soil on account of low and well distributed rainfall. In that year waterlogging did not occur to the usual extent. The rain sowings on such lands that became waterlogged during the monsoon should, therefore, be avoided. On the other hand, rain sowings can be practised on deep and well drained lands as their yield varied from 6 to 7 maunds per acre.

Pre-rain sown crops with well irrigation gave much higher yield than the rain sown crops on both the soil types. The highest yield of 12 maunds per acre was recorded in three experiments. Early sowings may, therefore, be practised where-ever irrigation water is available.

The best sowing period from the point of view of yields appeared to be earlier on waterlogged lands than on well drained lands. The optimum sowing time on water logged lands was found to be between 25th May and 10th June and for well drained lands from 1st June to 20th June.

The increase in yield obtained by early sowings was sufficiently high to meet the extra cost of irrigations (Rs. 25 to Rs. 40 per acre) and to leave a considerably high margin of profit in all the experiments.

(b) *Effect of spacing on yield*

The level of yield can be substantially increased by adopting closer spacing than the normally adopted spacing of 1¼ to 2½ ft. between rows. This was an important result of this investigation from a practical point of view.

The yields under different spacing obtained in seven experiments are given in Table XXIV (a).

TABLE XXIV(a)

Main effect of spacing on yield

(*Seed cotton in maunds per acre*)

Experiment No.	Spacings per plant						C.D. 5 per cent
	¼ sq. ft.	½ sq. ft.	1 sq. ft.	1½ sq. ft.	2 sq. ft.	3 sq. ft.	
I			3·99	3·90	3·20	2·56	0·42
V		7·01	6·01	5·31			0·94
VI		10·09	7·57		5·89		1·17
VIII	3·72	4·11	3·36	2·82			0·23
IX		5·12	3·66				0·53
X		1·87	1·36				0·66
XII		9·91	7·20				0·69

TABLE XXIV (b)

Main effect of spacing on yield

(*Seed cotton in maunds per acre*)

Experiment No.	Spacing between plants (inches)	Spacing between rows (in inches)								C.D. 5 per cent
		8½	12	15	17	21	24	30	34	
I	9			3·99			3·90	2·98		0·58
	18			3·42			2·89	2·23		1·60
V	6		6·90							
	8½	7·10			5·70					
	10½					4·70				
	12		6·30							
	15			5·90						

TABLE XXIV(b)—*contd.*

Main effect of spacing on yield

(*Seed cotton in maunds per acre*)

Experiment No.	Spacing between plants (inches)	Spacing between rows (in inches)								C.D. 5 per cent
		8¼	12	15	17	21	24	30	34	
VI	4½				9·50					1·99
	6		9·20				6·60			
	8½	11·40			8·40				4·50	
	12		7·90				6·10			
	17				7·00					
VIII	3		3·72							0·23
	6		4·11							
	12		3·36							
	18		2·82							
IX	6		5·12							0·53
	12		3·66							
X	6		1·87							0·66
	12		1·36							
XII	6		9·91							0·69
	12		7·20							

Half sq. ft. per plant equivalent to 9 in. between rows and 8 in. between plants or 12 in. between rows and 6 in. between plants was found to be the optimum spacing as shown in Table XXIV (b) ; spacing closer than ½ sq. ft. per plant reduced the yields.

(c) *Effect of nitrogen on yield*

In Table XXV (a) are shown the average and percentage responses to nitrogen in presence and absence of superphosphate and potash, obtained in the experiments conducted for the present study. The increases in yield per lb. of nitrogen are also calculated and are given in Table XXV(b).

It will be observed from the Table XXV(a) that responses to nitrogen were high and significant in all the 16 experiments. These universal increases in yield furnish the proof that nitrogenous manuring is an important factor in cotton growing. It is clear from the above results that the present status of nitrogen of the Malwa soils falls far below that necessary for maximal cotton production, thus indicating the acute deficiency of nitrogen for successful cotton production.

In experiments (IV, V, VI, XIII, XV, XVI, XVII, and XVIII) given in Table XXV(a) where more than one dose of nitrogen was tried out, it was found that there was an increase in yield with the increase in doses of nitrogen but the rate of increase declined with higher doses.

TABLE XXV(a)

Average increase in yield with nitrogen application

(Seed cotton in maunds per acre)

Experiment No.	Year	Yield of control	Increase with per lb. of N. per acre.										C.D. 5 per cent
			20	25	33	40	50	60	66	75	80	100	
II	1944	3·52				+1·48 (42·1)							0·67
VI	1945	6·20			+2·04 (32·9)				+2·91 (40·7)				1·17
X	1946	1·22					+0·98 (87·5)						0·16
XII	1947	7·72			+1·66 (21·5)								0·43
III	1945	7·00					+5·40 (77·1)						1·13
IV	1945	8·30			+3·10 (37·3)				+4·90 (59·0)				1·27
V	1945	3·71			+2·45 (66·0)				+4·76 (128·3)				0·94
VIII	1946	2·13					+1·59 (74·6)						0·93
IX	1946	3·34					+2·10 (62·9)						0·02
XI	1946	2·35	+0·73 (31·1)			+1·24 (52·8)		+1·91 (81·3)			+2·33 (99·1)	+2·66 (113·2)	1·22
XIII	1947	6·56		+3·18 (48·5)			+4·91 (74·9)			+5·85 (89·2)			0·58
XIV	1947	5·97					+6·29 (105·4)						0·90
XV	1948	6·35		+2·57 (40·5)			+3·95 (62·2)			+5·41 (85·2)			0·46
XVI	1948	5·69	+3·19 (56·1)			+3·76 (66·1)		+5·32 (93·5)			+5·53 (97·2)	+5·93 (104·2)	1·00
XVII	1949	2·53	+1·24 (49·0)			+2·09 (82·6)		+3·07 (121·3)			+3·85 (152·2)	+5·93 (104·2)	0·54
XVIII	1950	3·19	+1·61 (50·1)			+3·04 (95·3)		+3·54 (110·9)			+2·28 (71·5)	+5·65 (177·1)	1·22

NOTE.—Figures in brackets denote percentage increase over control.

The increases in yield with per pound of nitrogen, decreased with increase in doses of nitrogen in almost all the experiments (Table XXV (b)).

TABLE XXV (b)

Response in yield per pound of nitrogen

	Experiment No.	Year	Dose of Nitrogen									
			20	25	33	40	50	60	66	75	80	100
Waterlogged	II	1944				3·0						
	VI	1945			5·2				3·6			
	X	1946					1·7					
	XII	1947			4·1							
Well drained	III	1945					8·9					
	IV	1945			7·7				6·1			
	V	1945			6·1				5·9			
	VIII	1946					2·6					
	IX	1946					3·5					
	XI	1946	3·0			2·6		2·6			2·4	2·1
	XIII	1947		10·5			8·1			6·4		
	XIV	1947					10·4					
	XV	1948		8·5			6·5			5·9		
	XVI	1948	13·1			7·7		7·3			5·7	4·9
	XVII	1949	5·1			4·3		4·2			4·0	8·3
	XVIII	1950	6·7			6·3		4·9			2·4	4·7

It can be further concluded that the increase in yield per pound of nitrogen was lower in waterlogged fields (Experiments II, V, X and XII), and also in years of high rainfall, 1944 and 1946 (Experiments II, VIII, IX, X and XI) while the increases were high in well drained fields during years of normal rainfall. Though the magnitude of the increase in yield obtained as a result of manuring on waterlogged lands was low, the percentage increase over the control was nearly of the same order as those obtained in the well drained fields (Table XXI (a)). This was because the level of the yield on such lands was low on account of the operation of other factors and consequently the level of response to nitrogen was also low though it was normal when considered as percentage increase over the control. The seasonal and soil influences were thus also clear in these experiments.

Nitrogen was found to increase the yield of cotton crop ; this increase will be profitable only when the increase is enough to leave a balance after paying for the cost of manure. Considering the present costs of ammonium sulphate and seed

cotton which are approximately Rs. 0·75 per lb. of nitrogen and Rs. 0·5 per lb. of seed cotton respectively, the ratio (price per lb. of nitrogen/price per lb. of seed cotton) works out to be 1·5. Thus with an application of 1 lb. of nitrogen an increase of 1·5 lb. and above of seed cotton is required to ensure a profit by nitrogenous manuring with ammonium sulphate. In the experiments conducted, this ratio was more than 1·5 in all the cases and even larger doses of nitrogen upto 100 lb. were thus found to be economical (Table XXV-b). The applications of nitrogen in the form of ammonium sulphate, therefore, not only increased the yields but also gave economic returns.

(d) *The effect of phosphatic and potassic fertilizers on yield*

The effect of superphosphate and potash singly or in combination with one another and with nitrogen was studied in nine and six experiments respectively. The average increases in yield as a result of phosphatic and potassic manuring and percentage increases are given in Table XXVI.

TABLE XXVI

Average increase in yield with phosphate and potash application

Experiment No.	Yield of control (o p)	Increase with P_2O_5 in lb. per acre			C.D. 5 per cent	Yield of control O.K.	Increase with K_2O in lb. per acre			C.D. 5 per cent
		25	50	100			25	50	100	
VIII	3·27			+0·46 (14·1)		3·48			+0·04 (1·1)	
IX	4·06			+0·67 (16·5)	0·24	4·25			+0·28 (6·6)	
X	1·62			—0·03 (1·8)		1·59			+0·03 (1·9)	
XII	7·97			+1·16 (14·6)	0·43	8·40			+0·26 (3·1)	
XIII	9·78	+0·30 (3·1)	+0·49 (5·0)			10·04	+0·11 (1·1)	—0·10 (1·0)		
XV	8·81	+0·84 (9·5)	+0·74 (8·9)		0·40	9·42	—0·07 (0·8)	—0·18 (1·9)		
XVI	9·12	+0·65 (7·1)	+0·73 (8·0)							
XVII	4·38	+0·64 (14·6)	+0·92 (21·0)		0·65					
XVIII	5·00	+0·75 (15·0)	+1·89 (37·8)		1·85					

Note.—Figures in brackets denote percentage increases over control.

The results indicated that there was slightly beneficial effect of phosphate on yield while potash had practically no effect on yield. Although the effect of phosphate on yield was small, it was, however, significant in five cases out of nine.

Interrelation of different factors on yield

(a) *Effect of sowing date in combination with nitrogen on yield*

The relation of sowing date in combination with nitrogen was studied in seven experiments and the yield data is presented in Table XXVII.

Table XXVII

Yield of seed cotton in maunds per acre

	Experiment II (Waterlogged)				Experiment III (Well drained)			Experiment IV (Well drained)				Experiment VI (Waterlogged)		
	d1	d2	d3		d1	d2		d1	d2	d3		d1	d2	d3
	20/5	14/6	4/7		12/6	29/6		1/6	12/6	29/6		28/5	8/6	29/6
	6·17	4·08	0·32	0	10·0	3·9	0	10·4	9·8	4·8	0	9·95	8·02	0·64
n40	7·91	6·65	0·45	n50	15·2	9·6	n33	13·0	13·0	8·3	n33	12·52	10·95	1·26
							n66	15·4	15·4	9·0	n66	13·87	12·39	4·07
n40-0	1·74	2·57	0·13	n50-0	5·2	5·7	n33-0	2·6	3·2	3·5	n33-0	2·57	2·93	0·62
							n66-0	5·0	5·6	4·2	n66-0	3·92	4·37	0·43
C.D. 5 per cent (Interaction)		2·45				1·59			2·16			1·99		

	Experiment IX (Well drained)			Experiment X (Waterlogged)			Experiment XII (Waterlogged)	
	d1	d2		d1	d2		d1	d2
	1/6	16/6		1/6	16/6		1/6	4/7
0	4·61	2·07	0	1·91	0·32	0	11·32	4·13
n50	7·20	3·67	n50	3·59	0·61	n50	13·17	5·59
(n50-0)	2·59	1·60	(n50-0)	1·68	0·29	(n50-0)	1·85	1.46
C.D. 5 per cent Interaction		0·62			0·77			0·96

The rain sown crop on waterlogged lands gave slight and less economic increase in yields when manured either with sulphate of ammonia or groundnut cake while the increase in yield of the rain sown crop due to manuring was high on well drained lands (Table XXVII). The early sown crops, however, gave high increases in yield on both soil types.

Earlier sowings increased the amount of nutrients removed from the soil because the early sown plants attained larger size on account of favourable soil and weather conditions during the early stages of growth. Thus the added nitrogen was more effectively utilized by the early sown crop than the late sown crop which was not able to profit equally especially in waterlogged fields on account of suppressed vegetative growth.

(b) *Effect of sowing date in combination with spacing on yield*

The effect of spacing on early sown and rain sown crop on yield was determined in five experiments and the results are given in Table XXVIII.

In all the experiments, closely spaced crop whether sown early or late with rains gave significantly high yields. The results of these experiments were in favour of the necessity of adopting close spacing even when the crop was sown early before the rains. Thus close spacing of the crop was an absolute necessity under all conditions of sowing date and manuring.

TABLE XXVIII

Yield of seed cotton in maunds per acre

Experiment I				Experiment IV			
	d1	d2	d3		d1	d2	d3
	12/5	1/6	14/7		28/5	8/6	29/6
Close	3·94	6·51	0·67	Close	16·23	12·62	1·43
Medium	4·17	5·36	0·66	Medium	10·49	11·49	0·73
Wide	3·34	4·10	0·39	Wide	9·62	7·25	0·31
Close-medium	+0·23	+1·15	+0·01	Close-medium	%5·74	%1·13	%0·70
Medium-wide	+0·60	+2·41	+0·28	Medium-wide	+6·61	+5·27	+0·62
C.D. 5 per cent Interaction		0·73				1·99	

Experiment IX				Experiment X					Experiment XII		
	d1	d2			d1		d2			d1	d2
	1/6	16/6			1/6		16/6			1/6	4/17
Close	7·05		3·18	Close		3·21		0·53	Close	13·45	6·37
Medium	4·77		2·55	Medium		2·30		4·40	Medium	11·04	3·35
Close-medium	+2·28		+0·63	Close-medium		+0·91		+0·13	Close-medium	2·41	+3·02
C.D. 5 per cent Interaction		0·74				0·92			0·96		

The results obtained at Indore regarding the interaction of sowing date with spacing on yield differed from those obtained in the Punjab [Dastur and Mukhtar Singh 1944] where close spacing was found beneficial only for the late sown crop while it was not found advantageous for the early sown crop. The interaction of sowing date and spacing was, therefore, significant in the Punjab. At Indore, the magnitude of the increase by adopting closer spacing was more with early sowings, than with late sowings.

This difference in the relation of sowing date with spacing can be attributed to the difference in the vegetative structure of the cotton plant in the two tracts. The early sown cotton crop in the Punjab produced a very vigorous and dense growth. The close spacing was, therefore, not at all necessary as the ground was covered fully by widely spaced crop. That was not the case at Indore where the vegetative growth produced even by early June sown crop was small and closer spacing was found more necessary than the normal practice even for early sowings to cover the soil.

(c) *Effect of spacing in combination with nitrogen on yield*

The relation of spacing to nitrogen on yield was studied in six experiments and in all cases it was found that highest yields were obtained as a result of manuring on closely spaced crop. (Table XXIX).

Whenever the crop was manured either with 33 lb., 50 lb. or 66 lb. nitrogen per acre the highest yields were registered in the closest spacing of ½ sq. ft. per plant on both the soil types. It is, therefore, very necessary that closer spacing should be adopted to derive maximum benefit when manure was applied to the soil.

Table XXIX

Yield of seed cotton in maunds per acre

Experiment V				Experiment VI				Experiment VIII				
	Close	Medium	Wide		Close	Medium	Wide		Very close	Close	Medium	Wide
0	4·10	3·58	3·43	0	7·43	5·84	5·34	0	2·85	2·84	2·46	2·16
n33	7·07	5·88	5·54	n33	9·89	8·93	5·92	n50	4·59	5·28	4·26	3·43
n66	9·87	8·58	6·95	n66	12·96	7·95	6·43					
(n33-0)	+2·97	+2·30	+2·11	(n33-0)	+2·46	+3·09	+0·58	(n50-0)	+1·74	+2·34	+1·80	+1·33
(n66-0)	+5·77	+5·00	+3·52	(n66-0)	+5·53	+2·11	+1·09					
C.D. 5 per cent		1·60				1·99				3·19		

Experiment IX			Experiment X			Experiment XII		
	Close	Medium		Close	Medium		Close	Medium
0	3·94	2·75	0	1·34	0·89	0	8·95	6·50
n50	6·29	4·58	n50	2·40	1·80	n33	10·87	7·89
(n50-0)	+2·35	+1·83	(n50-0)	+1·06	+0·91	(n33-0)	+1·92	+1·39
C.D. 5 per cent Interaction		0·61			0·77			0·96

The increases were, however, statistically significant in three experiments out of six.

(d) *Effect of nitrogen in combination with phosphorus on yield*

The effect of nitrogen in combination with phosphorus, was studied in nine experiments and the increases in yield are indicated in Table XXX.

TABLE XXX

Increase in yield over unmanured (O. P.) plots

Experiment No.	Increase with P_2O_5	0	20	25	33	40	50	60	75	80	100	C.D. 5 per cent
VIII	100	—0·04					+0·95					
IX	100	+0·46					+0·88					
X	100	+0·06					—0·11					
XII	50	+1·04					+1·27					
XIII	25	—0·04		+0·45			+0·30		+0·50			
	50	+0·70		+0·64			+0·07		+0·54			
XV	25	+0·69		+0·24			+2·15		+0·26			
	50	+1·19		+0·18			+1·13		+0·49			
XVI	25	—0·31	+0·21			+0·85		+1·04		+1·48	+0·67	
	50	—0·57	+0·78			+0·16		—0·24		+1·13	+1·44	
XVII	25	+0·01	+0·88			+0·20		+0·57		+0·54	+1·59	
	50	—0·06	+0·63			+0·83		+1·20		+1·08	+1·85	
XVIII	25	—1·88	+1·32			+1·81		+0·87		+0·89	+1·44	
	50	+0·34	+3·44			+1·40		+0·25		+2·12	+3·84	

The extra crop from phosphatic manuring obtained in several of the experiments was more in the presence of nitrogenous manuring than in the no-nitrogen plot, but the differences were not statistically significant in majority of the experiments and in any case the great variability within these experiments makes this conclusion uncertain.

CONCLUSIONS

The rain sowings of American Upland cottons normally practised in the central India do not meet with favourable conditions for growth during the first two and a half months after sowings; consequently their vegetative structure remains small and subnormal producing a very small number of bolls. It has been conclusively shown by sowing date experiments that the cotton plant requires bright sunshine, higher temperatures and the absence of waterlogging in the soil for their normal growth during the early stages of its life cycle. Cotton sown towards the end of May up to the middle of June by well irrigation, i.e., only two to four weeks before their normal sowing time in vogue at present, is found to attain much greater height, internodes and dry weight per plant than the cotton sown with rains. Thus the

advantage gained during the first three weeks of the pre-monsoon conditions is reflected on the whole life cycle of the plant even though after three weeks they meet with the same weather conditions as the rain sown crop. It appears that during the period of high temperatures and the optimum moisture conditions of the soil there is a better development of the root system which enhances the shoot growth.

The cotton plant in Malwa produced growth in extension during the first 100 days after sowing while it puts on very little in dry matter during that period. This was probably the result of unfavourable weather conditions as low temperatures and cloudy days retarded the photosynthetic activity. The real increase in dry matter begins in September with the return of bright weather when the plant becomes photosynthetically active. At that stage the extension growth declines. The effect of favourable weather and soil conditions during the early stages of growth can be seen from the curves of the relative growth rate and the net assimilation rate. They are much higher in the early stages in the pre-monsoon sowings than in the rain sowings. Thus the functional activities are high and the crop is found to grow at a quicker rate. The pre-rain and the rain sowings showed marked increase in their functional activities again in September-October when the monsoon conditions disappeared and bright weather set in.

When the crop is sown early, the flowering phase also sets in earlier than in the case of the rain sown crop. This finding was in contrast with the finding of Dastur and Mukhtar Singh [1944] in the Punjab where late sown crop came into flowering almost about the same time as the early sown crop. Another important difference in the flowering activity of the American cotton plants in the Punjab and in Malwa was that flowering occurred in a flush showing a big peak in the Punjab while that was not the case in Malwa where the flowering was gradual by showing a small rise in the month of October.

Early sowing induced early flowering and there was also a slightly lowering effect on the first fruiting node, but the effect of sowing date on the first fruiting node was governed by soil and climatic conditions also.

The enhanced vegetative growth of the pre-monsoon crops results in better reproductive capacity. They produce greater number of bolls, greater boll weight and consequently higher yields than the rain sowings. The level of the yield in the pre monsoon sowings varied from seven to 12 maunds as against two to four maunds per acre in the rain sown crop. The better performance of pre-monsoon sowings than the rain sowings held good irrespective of the soil type. Better vegetative growth and higher yields were obtained on well drained as well as waterlogged lands. The level of yield in the case of the rain sown crop in waterlogged lands was extremely low and such lands should not be sown with cotton with rains.

The best sowing time appeared to be earlier on waterlogged lands than on well drained lands. The optimum sowing time on waterlogged lands was found to be between 25th May and 10th June and for well drained lands from 1st June to 20th June. The increase in yield obtained by early sowing was sufficiently high to meet extra cost of irrigation and leave a considerable margin of profit.

The main difficulty in practising early sowing in this tract is the unavailability of irrigation water. There is no canal irrigation at present but if the proposed Chambal Project materialises, cotton cultivation will be remunerative.

The effect of sowing date on fruiting coefficient was found to be interrelated with soil and seasonal conditions. In waterlogged fields or in years of high rainfall, early sowings gave higher fruiting coefficient than rain sowings. In well drained fields and in years of low rainfall, rain sowings gave higher fruiting coefficient than early sowings.

Early sowing was also found to be most potent factor for inducing earliness in plants. The percentage of the crop in the first picking was very high as compared with the rain sowings.

Spacing as a factor produced small differences in the vegetative as well as reproductive growth. Wider spacing produced slightly better plants with greater dry weight per plant but when the dry weight produced per unit area was considered, closer spacing was better than wider spacing. The same remark applied to boll number and yield. The boll number and yield though were higher on per plant basis but were lower on per unit area basis in the wider spacing than under closer spacing. There was no effect of wider spacing on boll weight which was the same as in the case of closely spaced crop with some exceptions. Though the yield per acre in closely spaced crop was higher than in widely spaced crop, the latter was more efficient in production of seed cotton. The fruiting coefficient was higher in widely spaced crop than in closely spaced crop. Similarly, the crop was earlier by 2 to 5 per cent in closer spacing than in wider spacing.

Nine inches between rows and 8 in. between plants or 12 in. between rows and 6 in. between plants were found to be the optimum spacing both for pre-rain sown and rain sown crop.

Nitrogen behaved like the early sowing date. Its application increased the vegetative as well as reproductive growth of the plant. It significantly increased the height, internode number, internodal length, and the dry weight per plant. It also increased the lateral growth more than the extension growth. Nitrogen treated plants grew vigorously soon after sowing after which the growth declined comparatively. The functional activities were higher in the unmanured plants than in nitrogen treated plants in the latter stages of growth because the untreated plants became more active after the termination of the monsoon season during which period their activities were suppressed from the beginning owing to adverse conditions. Nitrogen thus enhanced the vegetative growth in the early stages even though the weather conditions were not favourable for the rain sown crop.

The boll number, boll weight and yield all significantly increased when nitrogen was applied. The increase became greater in these characters as the level of nitrogen was increased. Nitrogen also like the early sowing had slightly lowering effect on the first fruiting node.

Nitrogen also increased the rate of flowering during the first half of the flowering phase. The rate of flowering was found to increase as the level of nitrogen was increased.

Nitrogen produced a remarkable effect on the rate of bolling which was much higher during the first half of the bolling period in the manured plants than in the case of unmanured plants. More bolls opened, when nitrogen was applied, in the early stages of bolling period making the crop early. The reverse was found to be the case in the later stages of bolling when unmanured plants showed an increased rate of bolling than the manured plants.

Nitrogen slightly increased the number of vegetative branches but it had greater increasing effect on fruiting branches, number of fruiting nodes and bolls borne on them. The effect on setting percentages was, however, not constant from season to season. Nitrogen did not affect the percentage distribution of the bolls on the different regions of the stem. The percentage of total number of bolls was equal on all the zones of the plants.

The efficiency of the crop for the production of seed cotton was found to increase on account of an application of nitrogen. Higher doses of nitrogen beyond 66 lb. per acre did not further increase the fruiting coefficient.

A very interesting finding of this investigation was the hastening effect produced by nitrogen on the maturity of the crop. The buds, flowers and opened bolls appeared 8 to 10 days earlier in the manured plants than in the unmanured plants. The rate of flowering and the rate of bolling were higher in the early stages in the manured plots than in the case of unmanured plots. Thus the arrival of the crop in the manured plots was earlier by about 12 per cent than in the control plots. Thus hastening effect on maturity and crop arrival of manuring was quite contrary to that found in the Punjab where manuring was found to make crop late by a fortnight.

The results of 16 trials point to the conclusion that the odds in favour of obtaining profits from nitrogenous manuring with two to three maunds of ammonium sulphate are very high and there are good prospects of profitable returns upto five maunds especially if the present high prices of seed cotton are maintained. The general responsiveness of American cotton to nitrogenous manuring is now fully established and there seems little likelihood that weather conditions, e.g. high rainfall and waterlogged conditions of the soil in some seasons, will render the application of these amounts unprofitable.

Phosphate was found to increase slightly the vegetative and the reproductive growth. The yield of seed cotton was also slightly higher in phosphate treated plots. The response, however, varied from experiment to experiment ; sometimes it occured only in combination with nitrogen and sometimes it was found to operate independently.

The application of potash showed no effect either on the vegetative or the reproductive growth of the crop in the Malwa conditions.

The results obtained on the interaction of sowing date with nitrogen on the vegetative growth were variable in different experiments. In some experiments the increases obtained as a result of application of nitrogen declined as the sowing date advanced while in other experiments there was no such decline. The early sowing gave higher increases in yield by nitrogen application than the rain sown crop. The increase also became greater as the level of nitrogen increased.

The effect of sowing date in combination with spacing did not come out constantly significant on any character. The height declined under each sowing as the spacing became wider and that was due to greater attack of Jassids in widely spaced crop than on closely spaced crop as demonstrated by Dastur *et al.* [1945]. The dry weight per plant on the other hand increased as the spacing became wider. Thus maximum height and dry weight were attained under the combination of close spacing with early sowing. There was also an increase in boll number as the spacing became closer under all sowings, but the maximum boll production occurred under the combination of close spacing with early sowing. The same remarks applied to yield. Thus close spacing and early sowing provided the optimum conditions for vegetative as well as reproductive growth. Thus early sowing, close spacing and manuring proved the best combination for vegetative and reproductive growth and the maximum yields of cotton can be obtained by adopting this practice.

Summary

The vegetative and reproductive growth of the American Upland cotton in the black cotton soils of Malwa under rainfed conditions are studied in 18 complex experiments and the effects of sowing time, spacing, nitrogen, phosphorus and potash on the various characters are determined separately and in combination with one another.

2. The cotton plant in this tract produces extension growth for the first 100 days after sowing but there is not much increase in dry matter due to unfavourable weather conditions during the monsoon months. The increase in dry matter occurred with the cessation of monsoon and the return of bright weather.

3. Early sowing by well irrigation, i.e. three weeks before the rains set in and manuring with nitrogen produced similar effects. Both the factors increased significantly the height, the dry weight, boll number, boll weight and yield, while spacing produced very small effect on these characters. Closer spacing produced more bolls and yield per unit area than wider spacing. Phosphorus had slightly increasing effect on vegetative and fruiting characters and potash had no effect.

4. The relative growth rate and the net assimilation rate are higher in the early stages of growth in the pre-rain sown crop than in the case of rain sown crop as the former are exposed in the early stages to favourable weather conditions such as bright sunshine, high temperature and favourable moisture conditions. The effect of nitrogen on growth was high during the first 30 days and during the later stages of growth nitrogen treated plants showed lower rate than untreated plants.

5. Early sowing and application of nitrogen had slightly lowering effect on first fruiting node and induced earliness in crop maturation.

6. The effect of sowing date on fruiting coefficient, i.e. the capacity for producing seed cotton per unit dry matter was interrelated with soil and climatic conditions while nitrogen and wider spacing had increasing effect on fruiting co-efficient,

7. Early sowing, manuring with nitrogen and close spacing proved to be the best combination for vegetative and the reproductive growth. Highest yields were registered under this combination. This finding held good for both the soil types, viz. well drained and waterlogged.

8. Application of nitrogen brought about an earlier maturity of the crop by nearly a fortnight. The flowers appeared ten days earlier. The rates of flowering and bolling were also found to be much higher in the early stages of the reproductive phase in the manured plants than in the control. The arrival of the crop was thus early by 10 per cent in the manured plots.

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POTASSIUM STATUS OF SOILS OF WESTERN INDIA—I

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(With one map)

POTASSIUM is known to exist in soil in four types of combinations [De Turk *et al.*, 1943] : (*a*) water soluble, (*b*) water insoluble, but readily displaceable by other bases, (*c*) water insoluble and not exchangeable—fixed, but readily extractable by acids and (*d*) less soluble form contained in the primary minerals as muscovite, biotite and felspars. The total potassium content of mineral soils except those of a markedly sandy nature is about two per cent [Peech, 1948], i.e. approximately 40,000 lb. per acre, furrow-slice. But the potassium problem of an average soil is not a question of presence but of availability. The exchangeable potassium content of a soil is often taken as a criterion of the fertility status of a soil [Chandler *et al.*, 1945]. From the results of correlation studies of potassium extracted by crops and that supplied by Iowa soils, Pratt [1951] has come to the conclusion that exchangeable potassium is the best single measurement of potassium availability of soils. From the study of Alabama soils, Pearson [1952] has shown that a close relationship exists between the original exchangeable potassium content of soils and the total potassium absorbed by crops. There is, however, considerable evidence that acid soluble potassium is also correlated with its availability. This fraction is believed to be a measure of the soil's reserve potassium which in time may become available to the plant [Sen, Deb and Bose, 1949]. Van der Marel [1947] recommended 25 per cent hydrochloric acid for the determination of available potassium in tropical soils. Rouse and Bertramson [1950] found that for 23 Indiana soils the non-exchangeable potassium extracted by boiling nitric acid treatment was closely related to the potassium supplying power of these soils as measured by cropping. Sen, Deb and Bose [1949] heated the soil with concentrated hydrochloric acid to determine the reserve potassium which may become available in time. In the present study, exchangeable potassium was determined by treatment with a normal neutral solution of ammonium acetate, and the acid soluble potassium was determined by boiling the soil with constant boiling hydrochloric acid (sp. gr. 1.125).

Base exchange capacity and degree of saturation

Wiklander and Gieseking [1948] have shown that the exchangeability of an absorbed ion is a function of the activity coefficient of that ion and other complementary ions held by the colloid, the cation exchange capacity and the degree of saturation of the ion in question. Base exchange capacities have, therefore, been determined and the degree of potassium saturation calculated.

Distribution of potassium in soil profile

For deep-rooted perennial crops like alfalfa, the readily available potassium of the sub-soil upto a depth of at least five feet is of considerable importance [Volk and Truog, 1934]. In order to know whether adequate supplies of potassium are available in sub-soil zones, a profile study was taken up and exchangeable and hydrochloric acid-soluble potassium and the degree of potassium saturation determined in four representative profiles.

Leaching losses

A study of the mechanical composition of *goradu* soil has shown that the per centsage of sand varies from 71 to 86 throughout its depth up to five feet. This indicate a very open porous soil with a tendency to excessive drainage. When such a soil is irrigated or there is rainfall, nutrients are dissolved and unless they are utilized by a growing crop, they will pass to a large extent to the lower depths. Lyon and Bizzell [1936] found that 77·3 and 63·9 lb. potassium were lost annually by leaching through silty clay loam and silt loam soils respectively. Hendric, and Welch [1927] found that on an average only 8·6 lb. potassium was lost by leaching annually. Hester and Shelton [1940] have obtained 11·1 lb. of loss per acre through a six inch layer of a surface sandy loam and a six-inch sub-soil layer in pot experiments. The minimum loss obtained by Kardos [1941] was 1 lb. on silt loam soils. In the present work leaching losses of potassium under natural rainfall condition and under artificial irrigation have been determined.

Material and Methods

Analytical procedure

1. Exchangeable potassium was determined by a modified form of the volumetric cobaltinitrite procedure suggested by Volk and Truog [1934] and revised later by Volk [1941].

2. Acid soluble potassium was determined by digesting the soil with constant boiling hydrochloric acid for six hours and estimating potassium in the extract by the same volumetric cobaltinitrite method.

3. Base exchange capacity was determined by the official A.O.A.C. [1945] method.

Collecting profile samples

Pits were dug to a depth of six feet and samples taken from the pit walls. The sampling was done at varying depths till a layer of *murum* or limestone was encountered. Where no such layer was encountered, sampling was done to a depth of five feet. For *goradu* and *kiari* soils which are very deep and where the differentiation in the horizons is not marked, sampling was done at specific depths. For clay loam soils sampling was done according to natural horizons.


AVAILABLE POTASSIUM
IN SOILS OF
GUJARAT AND SAURASHTRA
SCALE 1 INCH = 60 MILES
N
S
BANASKANTHA
MEHSANA
SABARKANTHA
PANCHMAHAL
SABARMATI RIVER
MAHI RIVER
AHMEDABAD
KAIRA
BARODA
NARBADA RIVER
BROACH
TAPTI RIVER
AMBIKA RIVER
SURAT
ZALAWAD
HALAR
SAURASHTRA
GOHILWAD
ARABIAN SEA
EXCHANGABLE POTASSIUM
0.25 TO 0.50 M.E. PER 100 GM. SOIL
0.50 " 0.75 " " " " "
0.75 " 1.00 " " " " "
1.00 " 1.50 " " " " "
ABOVE 1.50 " " " " "

I A R/56

Fig. 3

Estimating leaching losses

Earthen pots each of four gallon capacity were rendered impervious to water by coating with linseed oil. The pots had a hole of half inch diameter in the bottom. A cork fitted with a glass-tube allowed the leachate to flow into bottles placed underneath. Nine such pots were used. A two-inch layer of washed gravel was placed in each pot. They were then filled with 30 lb. of the soil which formed a layer seven inches thick. The pots were placed over tripods, and the leachate was collected in bottles placed under the pots. The pots were divided into three groups. In the first group nothing was sown, in the second and third groups *bajri* (*pennisetum. typhoideum*) and Guinea grass (*Panicum maximum*) were sown respectively. The pots were kept in the open throughout the rainy season. During the season about 32 litres of the leachate were callected in each pot. Aliquots of leachates were analysed. The total rainfall was 48·5 inches.

Three months afterwards, *bajri* and Guinea grass were again sown in the second and third groups respectively. After good growth had taken place, irrigation was given at intervals of seven days. The irrigation dose was six litres of water per pot and five such irrigations were given. Aliquots of leachates were analysed.

Soils studied

Sixty-five soil samples from the ploughed depth exhibiting a wide range of soil conditions have been chosen in this study. Though a systematic survey was not contemplated, samples selected represent fairly well the soil types of Western India. This consists mainly of Gujarat and Saurashtra. Gujarat can be divided roughly into three soil tracts: (i) the northern Gujarat, (ii) the southern Gujarat and (iii) the Panchmahal tract. In the northern Gujarat tract which comprises Ahmedabad, Mehsana and Kaira districts, the soil is alluvial of the Indo-Gangetic type and is called *goradu* from its colour and texture. *Goradu* soils are sandy in character varying from drift sands of the Mehsana and Ahmedabad districts to the rich loams of Kaira. They vary in colour from light ash to rich brown and do not crack. In the southern Gujarat tract which comprises Broach and Surat districts, the soils are (i) deep black, (ii) *bhatha*, (iii) *gorat* and (iv) *kiari* of alluvial character but not of Indo-Gangetic type. They are called 'black cotton' soils. *Bhatha* soils are red, brown or chocolate in colour and are formed from alluvium along with Tâpti and Narmada banks. Old *bhatha* soils are called *gorat*. *Kiaris* are rice soils in low lying areas receiving drainage water from the surrounding parts. In the Panchmahal tract the soils are light coloured, shallow and poor while in the low lying areas the soils are deep rich coloured loams retentive of moisture.

Saurashtra can be divided into three soil zones. The northern zone comprises Zalawad and some portions of Halar districts, in which the soils are shallow and predominantly sandy with occasional areas of silt and clay; they vary in colour from ash gray to brown. In the central zone consisting of Madhya Saurashtra, Gohilwad and portions of Halar districts, the soils are deep overlying a bed of *kankar*

and limestone, vary from sandy clay to clay loam and are calcareous. The southern zone consists of coastal alluvium, fairly deep, brownish to brownish black well drained soils on level land.

TABLE I

Exchangeable and hydrochloric acid-soluble potassium and base exchange capacities of Gujarat and Saurashtra soils

No.	Taluka	Village	Soil type	Exch. K. m.e./100 gm.	HCl soluble K. m.e./100 gm.	100 × Exch. K. / HCl Sol. K.	Base Exch. capacity	Degree of K. saturation per cent
1	2	3	4	5	6	7	8	9
			Ahmedabad District					
1	Dhandhuka	Bhalganda	Loam	1·36	9·85	13·91	32·00	4·25
2	do.	Tagadi	do.	0·99	6·06	16·33	39·20	2·53
3	Prantij	Prantij	Sandy loam	0·49	6·25	7·93	10·20	4·80
4	Viramgam	Jivapura	do.	0·77	6·14	12·54	7·81	9·85
5	do.	Kanz	Sandy	0·70	7·27	9·62	4·60	1·52
6	do.	Mandala	Sandy loam	0·86	7·64	11·26	10·50	8·19
			Baroda District					
7	Baroda	Bil	Sandy loam	0·69	9·25	7·53	20·31	3·39
8	do.	Por	do.	0·71	6·97	10·19	7·80	9·13
9	do.	Model Farm	do.	0·48	5·26	9·13	21·20	2·25
10	Chhota Udepur	Chhota Udepur	Sandy clay	0·52	6·50	8·00	17·33	3·00
11	Dabhoi	Dabhoi	Loam	0·84	6·26	13·42	28·89	2·90
12	Karjan	Bhekhada	Clayey (Black cotton soil)	0·88	6·97	12·62	50·00	1·76

TABLE I—*contd.*

Exchangeable and hydrochloric acid-soluble potassium and base exchange capacities of Gujarat and Saurashtra soils

No. 1	Taluka 2	Village 3	Soil type 4	Exch. K. m.e./100 gm. 5	HCl soluble K. m.e./100 gm. 6	100× Exch. K. / HCl Sol. K. 7	Base Exch. capacity 8	Degree of K. saturation per cent 9
			Broach District					
13	Ankleshwar	Andada	Clayey (black cotton soil)	1·46	9·63	15·16	50·50	2·89
14	do.	Diva	do.	1·64	10·00	16·40	60·50	2·71
15	do.	Pungam	Clayey	0·90	7·50	12·00	45·51	1·95
16	Broach	Shahpura	do.	1·44	10·91	13·19	63·00	2·29
17	Vaghera	Vahiad	do.	1·52	12·51	12·15	60·20	2·52
			Kaira District					
18	Borsad	Borsad	Sandy loam (*goradu*)	0·69	4·93	13·99	11·11	6·21
19	do.	Dedarda	do.	1·32	12·05	80·95	20·40	6·44
20	Anand	Institute Farm	do.	0·45	5·50	8·18	9·91	4·54
21	do.	Mogar	do.	0·47	5·23	8·98	7·59	6·19
22	Bhadran	Bhadran	do.	0·61	7·65	7·97	9·29	6·57
23	Matar	Alindra	Loam	1·00	9·02	11·09	10·70	9·35
24	do.	Matar	do.	0·56	9·17	6·11	19·60	2·81
25	do.	Navagam	Clay loam	1·22	11·26	10·83	25·51	4·78
26	do.	Ratanpur	do.	1·13	10·38	10·88	30·50	3·71
27	do.	Sandhana	do.	0·68	5·87	11·58	25·82	2·57
28	Mehemdabad	Dhobikui	Sandy loam (*goradu*)	0·81	9·55	8·47	14·50	5·58
29	Nadiad	Bhilodra	do.	1·06	7·09	14·95	15·79	6·71
30	do.	Dabhan	do.	0·87	7·69	11·31	15·81	5·50
31	do.	Kaira	do.	1·05	8·71	12·05	17·90	5·86
32	do.	Mahudha	Loam	0·99	10·50	9·42	20·48	4·83
33	do.	Nadiad	Sandy loam (*goradu*)	0·71	7·65	9·28	16·70	4·25
34	Vadasinor	Jorapur	do.	1·05	10·00	10·50	15·51	6·76
35	Petlad	Agas	do.	0·46	4·89	9·40	10·70	4·29
			Mehsana District					
36	Mehsana	Deodarda	Sandy loam	0·60	6·97	8·61	14·88	4·03
37	Harij	Harij	Clayey	0·61	10·15	6·01	68·21	0·89
38	Jagudan	Jagudan	do.	0·51	9·17	5·57	67·90	0·75
39	Siddhpur	Bhunav	Sandy	0·56	6·14	9·12	6·71	8·33
40	Visnagar	Gunjana	do.	0·36	4·17	8·63	8·11	4·43
41	do.	Vasna	do.	0·46	4·77	9·64	3·19	8·86
42	do.	Vishupura	do.	0·35	4·77	7·33	7·81	4·48

TABLE I—*contd.*

Exchangeable and hydrochloric acid-soluble potassium and base exchange capacities of Gujarat and Saurashtra soils

No.	Taluka	Village	Soil type	Exch. K. m.e./100 gm.	HCl soluble K. m.e./100 gm.	100 × Exch. K. / HCl Sol. K.	Base Exch. capacity	Degree of K. saturation per cent
1	2	3	4	5	6	7	8	9
			Panchmahals District					
43	Zalod	Zalod	Sandy clay	0·44	6·38	6·89	15·52	2·83
44	Lunawada	Lunawada	do.	0·52	6·95	7·48	15·92	3·26
			Surat District					
45	Bulsar	Dharampur	Clayey	0·46	7·26	6·33	30·51	1·50
46	Bardoli	Degama	do.	0·64	5·39	11·87	37·51	1·70
47	Chikhali	Ranakuva	do.	0·61	9·85	6·19	46·08	1·32
48	Kosamba	Kosamba	Sandy clay	0·47	7·14	6·58	21·62	2·17
49	Mahuva	Fulwadi	Clayey	0·41	5·23	7·83	36·42	1·12
50	Maroli	Vala	do.	0·60	7·01	8·55	28·50	2·10
51	Navsari	Pacharwad	do.	0·49	6·38	7·68	52·20	0·94
52	Olpad	Olpad	Clayey (black cotton)	1·01	6·89	14·80	60·53	1·67
53	Vesma	Vesma	do.	0·81	7·36	8·65	54·71	1·47
			Saurashtra					
54	Chorwad	Mahlipar	Calcareous clay	2·41	12·51	19·27	14·90	16·17
55	Dhrangadhra	Mathar	Sandy	0·38	3·71	10·24	6·70	5·67
56	Dwarka	Dwarka	Calyloam	0·63	12·51	5·04	53·70	1·17
57	Godha	Valukad	do.	0·60	6·44	9·32	51·61	1·16
58	Gondal	Motadahisara	do.	0·77	8·94	8·61	21·90	3·52
59	do.	Supedi	do.	0·55	6·90	7·97	33·52	1·64
60	Morbi	Morbi	Sandy loam	0·63	5·83	10·80	22·11	2·85
61	Rajkot	Kewada wadi	Sandy clay	0·64	5·30	12·08	29·21	2·19
62	Sorath	Kodinar	do.	0·62	6·29	9·86	15·81	3·92
63	Upleta	Nani Vavdi	Calcareous clay	0·60	6·82	8·80	32·51	1·85
64	Vankaner	Bhojpara	Sandy loam	0·46	3·56	12·92	13·69	3·36
65	Zalawar	Limadi	Sandy clay	0·52	6·51	7·99	26·01	1·99

Results and Discussion

From Table I it is observed that the variation in the content of exchangeable potassium is rather large, the lowest figure being 0·35 m.e. per 100 gm. for a soil in Mehsana and the highest being 1·64 m.e. for a soil in Broach leaving aside the extraordinarily high figure of 2·41 for a sea-coast soil in Saurashtra. The soils can be divided into four groups (Table II):

Table II

Groups of exchangeable and acid-soluble potassium

Group	Exch. K m. e./100 gm.	Number of sites											Range of HCl soluble K. m. e./100 gm.	Correlation coefficient
			HCl soluble K. m. e./100 g.m.											
			3	4	5	6	7	8	9	10	11	12		
	0·3 to 0·4	3	1	2	..	..	..	..	..	..	..	..		
	0·4 to 0·5	12	1	2	4	3	2	..	..	..	..	..		
I	0·3 to 0·5	15											3 to 5	r=0·5344
	0·5 to 0·6	11	..	..	..	8	1	..	2	..	..	..		
	0·6 to 0·7	12	..	1	4	1	2	..	2	1	..	1		
II	0·5 to 0·7	23											5 to 6·5	r=0·0812
	0·7 to 0·8	4	..	..	..	2	1	1	..	..	..	..		
	0·8 to 0·9	6	..	..	..	2	2	..	2	..	..	..		
	0·9 to 1·0	3	..	..	..	1	1	..	..	1	..	..		
	1·0 to 1·1	5	..	..	..	1	1	1	1	1	..	..		
III	0·7 to 1·1	18											6·5 to 9	r=0·2392
	1·1 to 1·2	1	..	..	..	..	..	..	..	1	..	..		
	1·2 to 1·3	1	..	..	..	..	..	..	..	..	1	..		
	1·3 to 1·4	2	..	..	..	..	..	..	1	..	..	1		
	1·4 to 1·5	2	..	..	..	..	..	..	1	1	..	..		
	1·5 to 1·6	1	..	..	..	..	..	..	..	..	..	1		
	1·6 to 2·4	2	..	..	..	..	..	..	..	1	..	1		
IV	1·1 to 2·4	9											9 to 12	r=0·4287
	Total	65	for all samples taken as a whole										r=0·7069	

The soils of Ahmedabad, Kaira and Baroda are usually sandy loams or loams and a major number of these soils are evenly distributed in the first three groups. According to textural classification, the soils of Broach and Surat are similar, both being classed as black cotton soils but they differ in their content of exchangeable potassium. The Surat soils contain less exchangeable potassium, and are evenly distributed in the first three groups. The Broach soils on the other hand are rich in exchangeable potassium and are almost evenly distributed in groups III and IV. The soils of Mehsana, the Panchmahals and Saurashtra are comparatively low in exchangeable potassium and the majority of the soils from these are as in groups I or II.

Hydrochloric acid-soluble potassium is believed to be a measure of reserve potassium which in time may become available. The reserve potassium is about 10 to 20 times the exchangeable potassium. In Gujarat, in all the districts except

Broach, the acid soluble potassium is neither too high nor too low. In Broach, however, it is high. This is to be expected of a highly clayey soil of Broach. Working on red or laterite soils of India, Sen *et al.*, [1949] found no correlation between the two types of potassium. It is still significant to observe that the use of acid soluble potassium can be occasionally made as a criterion of availability. As can be seen from Table II, lower availability is generally associated with low values of acid-soluble potassium. A correlation between the exchangeable potassium and acid-soluble potassium has been worked out for all the samples and for the groups which appear to be related. The correlation factors are given in Table II. The results show that as a whole there is a correlation between the two at 1 per cent level, but it is not so within the groups, and, therefore, the use of acid-soluble potassium as a test of availability should be made with caution. For low values, however, the correlation is greater. The limits of acid-soluble potassium for the different groups are given in column 5 of Table II.

The availability of replaceable potassium depends not only on the total number of potassium ions but also on the proportion of potassium ions to the total number of absorbed ions [Hoagland, 1944]. A study of the degree of potassium saturation has, therefore, been made and the soils studied during the present investigation can again be classed into five groups on the basis of this ratio as under :

Group	Range of degree of K. saturation	Number of sites
Group I	Below 1·0	3
Group II	1·0 to 3·0	28
Group III	3·0 to 6·0	22
Group IV	6·0 to 9·0	8
Group V	above 9·0	4

Very few soils fall in Group I showing that the degree of potassium saturation is above 1 in the majority of soils of this tract. The clayey soils of Surat and Broach fall mostly in Group II, while the loams of Kaira are richer and fall in Group III. A few soils fall in Groups IV and V.

TABLE III

Exchangeable and HCl soluble K and the degree of K saturation in the profiles of Gujarat and Saurashtra soils

Soil	Scale	Exch. K.i.e./ 100 gm.	HCl sol. K.m.e./ 100 gm.	100 × Exch. K / HCl Sol. K.	Base Exch. capacity	Degree of K. saturation p. c.	pH
1	2	3	4	5	6	7	8
Goradu (Gujarat)	0″-6″	0·66	6·90	9·56	9·80	6·74	7·5
	6″-1′	0·45	6·25	7·20	9·19	4·89	7·5
	1′-2′	0·45	7·16	6·28	10·51	4·28	7·2
	2′-3′	0·48	7·91	6·07	14·61	3·28	7·2
	3′-4′	0·53	8·19	6·47	17·02	3·11	7·1
	4′-5′	0·48	8·34	5·75	17·90	2·68	7·2

TABLE III—*contd.*

Exchangeable and HCl soluble K and the degree of K saturation in the profiles of Gujarat and Saurashtra soils

Soil	Scale	Exch. K.m.e./ 100 gm.	HCl Sol. K.m.e./ 100 gm.	Exch. K / HCl Sol. K.	Base Exch. capacity	Degree of K. saturation p. c.	pH
1	2	3	4	5	6	7	8
Kiari (Gujarat)	0″-6″	0·75	12·92	5·80	29·88	2·51	7·6
	6″-1′	0·68	13·03	5·22	31·27	2·17	7·6
	1′-2′	0·73	13·53	5·39	31·51	2·32	7·2
	2′-3′	0·73	13·75	5·31	31·62	2·31	7·4
	3′-4′	0·77	13·72	5·61	33·00	2·33	7·0
	4′-5′	0·73	15·53	4·70	35·11	2·08	7·4
Clay loam (Saurashtra)	0″-6″	0·60	6·82	8·79	32·49	1·84	7·9
	6″-1½′	0·33	5·61	5·88	30·50	1·08	7·6
	1½′-2½′	0·30	5·52	5·61	26·18	1·14	7·8
	2½′-3½′	0·28	5·99	4·67	27·51	1·01	7·8
	3½′-4½′	0·32	7·50	4·26	26·28	1·21	7·8
Clay loam (Saurashtra)	0″-6″	0·55	6·89	7·98	34·50	1·59	8·0
	6″-1½′	0·35	5·83	6·00	29·88	1·17	8·2
	1½′-2′	0·29	5·00	5·80	26·87	1·07	8·2
	2′-3′	0·27	5·76	4·68	26·08	1·03	8·2
	3′-4′	0·27	5·08	5·31	25·11	1·07	8·2
	4′-5′	0·28	4·85	5·79	20·12	1·39	8·2

Potassium in profile

Table III gives the exchangeable and acid-soluble potassium and degree of potassium saturation of profiles of typical *goradu* and *kiari* soils and two clay loams. It is found that the top six-inch layer of the *goradu* soil profile with base exchange capacity 9·80 has 0·66 m.e. exchangeable potassium per 100 gm. soil whereas the next six-inch layer with base exchange capacity only slightly less has 0.45 m.e. exchangeable potassium per 100 gm. soil. The decrease in exchangeable potassium continues upto 2 ft. depth. Then it increases up to 4 ft. This would be naturally expected in view of an increase in the base exchange capacity. Then it slightly decreases in the next one foot layer. The acid-soluble potassium in the surface six-inch soil is about 10 times the exchangeable potassium in the same depth of the soil. In line with the decrease in base exchange capacity, it decreases in the next six-inch layer after which it steadily increases with increase in base exchange capacity. The degree of potassium saturation and exchangeable potassium per cent of the acid soluble potassium decrease with depth. The pH varies from 7·5 to 7·1.

The *kiari* soil profile has about 12 per cent more exchangeable potassium in the top six-inch layer than the corresponding *goradu* soil. Like the *goradu* soil profile there is a decrease in the next six-inch layer in spite of higher base exchange capacity. Probably this is a zone of intense root activity and nutrient depletion. Further on, there is no decrease upto 3 ft. Then, with increase in base exchange capacity, potassium increases in the next one foot layer. Finally it decreases in spite of a rise in base exchange capacity. Obviously there is less weathering.

A marked contrast is revealed by the *goradu* and *kiari* soil profiles. In the *goradu* soil the difference in exchangeable potassium between the top and the 5 ft. deep layers is eight times the corresponding difference in the *kiari* soil profile of the same tract and having the same genetic history. The degree of potassium saturation decreases with depth in the *goradu* soil profile while in the *kiari* soil profile it is practically constant. It is significant to note that in spite of lower exchangeable potassium, *goradu* soil profile has a higher degree of potassium saturation than the *kiari* soil at any depth of the profile.

A profile study of clay loam soils presents a different picture. They are more clayey, have distinct horizons, are only 4½ ft. deep and are highly calcareous. In one of these, exchangeable potassium which is 0·60 m.e. in the top six-inch layer decreases by more than 40 per cent in the next one-foot layer. The decrease continues upto the upper B horizon. The exchangeable potassium per cent of acid-soluble potassium steadily decreases with depth. The degree of potassium saturation is less than half of the corresponding depth sample of the *goradu* and *kiari* soils. The pH is also higher than that of *goradu* and *kiari* soil profiles.

TABLE IV

Leaching losses through rain-fed and irrigated goradu *soil*

Pot No.	Crop	Rain-fed				Irrigated			
		Leachate collected (litres)	K. leached		Average loss per acre (lb.)	Leachate collected (litres)	K. leached		Average loss per acre (lb.)
			Per pot m.e.	Per acre (lb.)			Per pot i.e.	Per acre (lb.)	
1	*nil*	32·10	5·31	30·8		11·55	2·49	14·5	13·5
2	*nil*	32·05	4·88	28·2	29·7	11·25	2·35	13·1	
3	*nil*	31·25	5·23	30·2		11·70	2·29	12·8	
4	*Bajri*	32·00	4·39	25·5		10·80	2·06	11·4	11·3
5	*(Peniset u m*	31·70	3·86	22·2	24·0	10·20	2·26	12·6	
6	*typhoideum)*	31·50	4·22	24·4		11·55	1·71	9·9	
7	Guinea grass	30·50	3·49	20·2		11·00	1·62	0·4	11·1
8	*(Panicum*	32·00	3·81	22·0	21·1	11·15	2·08	11·5	
9	*maximum)*	29·90	3·63	21·2	..	11·14	2·24	12·5	

Leaching losses

Table IV gives the leaching losses of potassium in rainfed and irrigated *goradu* soil. It is found that on an average 29·7 lb. of potassium per acre is leached under rainfed condition when no crop is taken, and 24·0 and 21·1 lb. when *bajri* and Guinea grass are grown respectively. It should be noted that the year was of unusually heavy rainfall, viz. 48·5 inches, the normal rainfall being 25 to 30 inches per year. The quantities leached in irrigated pots were 13·5, 11·3 and 11·1 lb. per acre when no crop was taken and when *bajri* and Guinea grass were grown respectively. It is obvious that leaching loss is less when a crop is grown. Volk [1940], working on Alabama soils, found that the leaching losses were reduced when winter legumes were grown. During his lysimeter experiments on the vertical transport of plant nutrients through silt loam soils, Kardos [1948] found that the loss of potassium

by leaching was less in cultivated soils than in uncultivated ones. From the present experiments it is clear that the loss of potassium due to leaching per year will be about 11 to 30 lb. per acre. It should be noted that in the experimental conditions water moves more freely through the soil than through the same depth in its natural undisturbed condition in the field, for the soil in the pots rests on a bed of free draining gravel. In contrast, the top soil in the field rests on a low draining subsoil. Moreover the pot walls extend up above the soil so that no rain water is lost as run off and consequently more percolation would be expected than from a similar soil under field conditions. Hence the maximum loss is about 30 lb. if the land is fallow and 24 lb. if the land is cultivated. This finding is based on pot experiments carried out in a year of unusually high rain-fall.

Conclusion

The exchangeable potassium in soils of western India varies from 0·35 m.e. to 1·64 m.e. per 100 gm., i.e. 273 to 1,279 lb. per acre. Taking into consideration the leaching loss of 30 lb. that is likely to occur, the available potassium in the surface soils is about 240 lb. per acre. Bray [1945] working with Illinois soils has correlated the effect of potassium fertilization on yield of corn, clover, wheat, oats and soybean and his results indicate that soils containing 140 lb. or more of exchangeable potassium per acre in the surface $6\frac{2}{3}$ inches of soil will give good crop growth and that soils containing 90 to 140 lb. will probably respond to potassium fertilization. Volk and Truog [1934] place the dividing line between deficient and non-deficient soils at about 165 lb. per acre. Murphy [1934] states that soils of Oklahama, which contain 120 lb. of exchangeable potassium per acre, will support good crop growth although occasional responses to potassium fertilization may be obtained on soils containing upto 200 lb. per acre. As the minimum value obtained during the present work even after making allowance for leaching losses is much above the limiting figures given by the above workers, it is not unreasonable to assume that our soils are well supplied with readily available potassium. Commenting on the manurial experiments conducted for 35 years in Bombay State, Sahasrabuddhe [1934] observed that chillies and tobacco are the only crops that respond to potassium fertilization. One would naturally conclude from this that the level of available potassium in the soils of western India is sufficiently high for a crop.

Fruit trees take nutrients from lower depths. Exact requirements of available potassium for fruit trees are not known. Lilleland and Brown [1938] from the study of prunes have put the requirement at 100 p.p.m. for 200 lb. per acre of exchangeable potassium. Reuther's [1941] estimate is also similar. A study of the profiles made here shows that the available potassium is more than this limit in all the horizons. It may be therefore, stated that available potassium in our soils is well above the safety line.

Summary

1. Sixty-five samples representing different soil types of western India have been examined for exchangeable and acid-soluble potassium and the degree of potassium saturation. Exchangeable potassium varies from 0·35 to 1·64 m.e. per

100 gm. soil or 273 to 1,279 lb. per acre. Hydrochloric-acid-soluble potassium varies from 3·56 to 12·51 m.e. per 100 gm. or 2,777 to 9,758 lb. per acre. The degree of potassium saturation varies from 0·75 to 9·90.

2. Similar determinations have been made in four profiles of *goradu* and *kiari* soils of Gujarat and clay loam soils of Saurashtra. There is a decrease in exhangeable potassium in all the soil profiles as one goes deeper but the decrease is more pronounced in Saurashtra soil profiles than in Gujarat soils.

3. Leaching losses of potassium in rainfed and irrigated *goradu* soil have been estimated. The average loss in rainfed soil is 29·7 lb. per acre per season when no crop is taken, but the loss is reduced when *bajri* or Guinea grass is grown. This loss in irrigated soil is 13·5 lb. per acre when no crop is taken and it is less when *bajri* or Guinea grass is grown.

4. There is sufficient readily available potassium for a crop during the growing season in the soils of western India.

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STUDIES ON *JOWAR* FODDER (*ANDROPOGON SORGHUM*)

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THE composition of grasses and fodder crops is known to be affected by several factors. Ramiah[20], Iyer[10] and Surin[26] reported that species, maturity, climatic conditions, method of cultivation, soil, etc. affect the composition of fodders. Among these factors, maturity or stage of growth is an important factor and much work on it has been reported indicating variations in the observations depending upon varying conditions.

In previous studies, many workers, 13, 3, 6, 27, 19, 23, 4, 17, 11, 12, 18 and 28 working on different grasses or fodder crops pointed out that as the maturity advanced the nutritive value of a grass or fodder progressively decreased with regard to protein, ether extract and phosphate, while the crude fibre content increased. With regard to N. F. E. and calcium contents varying results have been reported. Shrivastava *et al.*,[23] and Lakke Gowda[11,12] reported an increase in carbohydrates with progressive maturity in berseem and *jowar*, while Narendra Nath and Das[17] observed its decrease in the grasses they studied. Staples *et al.*[24], reported that dry matter, ether extract, crude fibre and nitrogen-free extract in prairie hays were not affected seriously by the time of harvest. Talpatra *et. al.*[27], Anwar Ullah[2], Barua *et al.*,[4] Lakke Gowda[12], and Gastler and Moxon,[9] reported a decreasing trend of calcium with maturity, in acquatic grasses, venezuela grass, *jowar* fodder and in other grasses they studied. Lander,[13] reported that calcium tends to remain steady in grasses, while Shrivastava *et. al.*,[23] reported an increase in the calcium content upto flowering stage in berseem. Similarly Ray and Sen[21], observed that lime and phosphate contents in fodders increased with maturity and rainfall.

It is obvious that although with growth, the trends of change in protein and phosphorus are identical in almost all herbages, the variations in other nutrients are different as has been observed in numerous plants under varying conditions of soil, climate and method of cultivation. Hence the present investigation was undertaken with a view to studying the variations in the composition of some cereal fodders with growth under the conditions of Kaira District in Bombay State.

Experimental

(a) *Varieties of* jowar *fodder*. This article deals with the fodder crop of *jowar* (*Andropogon sorghum*). Two varieties of *jowar* fodder are common in this area viz. *Sundhia* and *Sholapuri*. The former is grown in monsoon and summer in 'Charotar' tract which includes Anand, Borsad, Petlad and Thasara talukas; and the latter is grown in winter as a non-irrigated crop in 'Bhal' tract, which includes Matar and Cambay talukas. Samples of both the varieties were taken at specified stages.

(b) *Method of sample collection.* After a preliminary survey of the area within about 12 miles radius from Anand, representative villages were selected for the collection of samples. Each village was divided into four blocks and samples were taken from several places in each block. All the material from four blocks was mixed and a composite sample was taken to represent the villages. The samples were chaffed and milled into powder before analysis.

(c) *Methods of analysis.* A. O. A. C. (1950) methods of analysis were followed.

Results and Discussion

The stagewise composition of summer *Sundhia jowar* fodder from different villages is given in Table I.

Table I

Composition of summer Sundhia jowar *fodder at specified stages from different villages*
(*On oven dry basis*)

Stage	Bhalej Village			Chaklasi Village			Karamsad Village			Napa Village		
	Young	Flowering	Straw	Young	Flowering	Straw	Young	Flowering	Straw	Young	Flowering	Straw
Crude protein	10·37	5·66	4·27	20·50	10·32	3·17	9·05	9·61	3·56	11·29	4·66	5·07
E. ext.	2·45	1·08	2·13	3·66	3·42	1·50	1·88	1·75	1·90	2·22	1·53	2·56
N. F. E.	50·36	57·77	52·08	39·84	47·56	49·05	45·85	45·04	52·69	45·61	51·27	53·99
C. fibre	27·20	29·40	32·40	23·50	28·40	36·80	30·04	30·25	33·30	25·33	34·60	27·55
Ash	9·62	6·09	9·12	12·50	10·30	9·48	13·18	13·40	8·55	15·55	7·94	10·83
Silica	4·00	3·94	4·98	3·60	6·26	4·54	6·01	6·75	4·24	6·69	4·75	6·72
P_2O_5	0·83	0·57	0·37	1·09	0·79	0·31	1·04	1·11	0·63	0·82	0·74	0·78
CaO	1·17	0·54	0·67	1·34	0·69	0·92	0·64	0·76	0·64	0·78	0·40	0·99

A summary of the statistical analysis of these results is given in Table II.

Table II

Composition of summer Sundhia jowar

Stage	C. Protein	E. extract	N. F. E.	Crude fibre	P_2O_5	CaO
Young	12·80	2·55	45·42	26·52	0·94	0·98
Flowering	7·56	1·64	50·40	30·66	0·80	0·60
Straw	4·02	2·02	51·17	33·30	0·52	0·80
Significance (F)						
Villages	No	No	No	No	No	No
Stages	Yes*	No	No	Yes†	Yes*	No
S. E. (stages)	1·66	0·39	1·52	0·80	0·09	0·10

* Significant at 5 per cent level
† Significant at 1 per cent level

From Tables I and II it can be seen that crude protein and phosphate contents decrease significantly with maturity. As concluded by Dlaisdell and others[7] the fall may be attributed to the transfer of the nutrients to the roots or may be due to their distribution in the increased material during subsequent growth. The parallelism in these nutrients appears to be constitutional as observed by Strebeyko[25], Alway and Nelson[1]. They stated that a deficiency of phosphorus inhibits

the absorption of nitrogen and *vice-versa*. N. F. E. and crude fibre increase with maturity. The increase in N. F. E., however, was not statistically significant. The variations in other nutrients were irregular and non-significant.

Statistical analysis further revealed that the differences between the samples of fodder collected from different villages were not significant. It would, however, be worthwhile to see how the composition of the fodder from distant places in the country vary. For this purpose, the compositions of the fodder from Bangalore, Bihar and Punjab are compared with that of the fodder in this tract.

TABLE III

Comparison of jowar *fodder from different parts of India*

Stage	Bangalore*			Bihar*		Punjab*			Anand (Gujarat)		
	Young	Prime	Ripe	Prime	Ripe	Young	Prime	Ripe	Young	Prime	Ripe
C. Protein	8·91	7·75	4·63	2·85	3·49	5·21	3·76	3·87	12·80	7·56	4·02
E. Extract	2·14	1·73	1·16	1·18	1·45	1·37	1·40	1·56	2·55	1·64	2·02
N. F. E.	44·42	49·61	47·49	57·48	58·49	45·59	53·34	53·78	45·42	50·41	51·17
C. Fibre	35·13	32·36	38·66	30·91	30·89	38·87	35·13	33·63	26·52	30·66	33·30
Ash	9·40	8·55	8·06	7·58	5·68	8·96	6·37	7·11	12·71	9·43	9·50
Silica	2·92	3·59	3·21	2·62	3·27	4·18	2·97	3·61	5·75	5·42	5·12
(P_2O_5)	0·57	..	0·48	0·42	0·33	0·41	0·32	0·25	0·94	0·80	0·52
(CaO)	0·51	..	0·35	0·59	0·62	0·69	0·59	0·63	0·98	0·60	0·80

* From *I. C. A. R. Bulletin No. 25*

From the data in Table III it can be seen that the protein content in the fodder from Anand decreases with maturity as is the case in the fodder from Bangalore. Such decline is also reported by Lakke Gowda [11,12] in *kaki* and white varities of *jowar*. However, in the fodders from Punjab and Bihar, the protein content in the ripe stage is somewhat higher than in the prime stage as was also observed in the fodder from village Napa in the present study. The ether extract in the ripe stage of the fodder from Anand, Punjab and Bihar is more than that in the prime stage, while in the fodder from Bangalore there is a continuous decrease with maturity. The N. F. E. and crude fibre contents of the fodder from Anand showed an increasing trend similar to that reported by Lakke Gowda[11,12] in *kaki* and white *jowar* fodder. In Bangalore, Bihar and Punjab fodders, these showed irregular variations, particularly the fodder from Punjab showed a reverse trend in crude fibre. The phosphate content in the fodder from all the places showed a decreasing trend and the calcium content seemed to increase somewhat, in the ripe stage after a fall in the prime stage.

The overall composition of the fodder indicates that the fodder from Bihar is richer in N. F. E. while that from Anand is richer in minerals particularly calcium.

Comparison of two varieties of jowar *fodder.*

It is pointed out that two varieties of *jowar* fodder, viz *Sholapuri* and *Sundhia* are commonly grown in this part. The compositions of these two varieties are given in Table IV.

TABLE IV

Composition of kharif Sholapuri *and* Sundhia jowar *straws*

Variety	C. Protein	E. Extract	N.F.E.	C. Fibre	Ash	Silica	P_2O_5	CaO
(3) *Sholapuri*	3·51	1·35	61·09	26·67	7·39	3·71	0·39	0·60
(4) *Sundhia*	4·02	2·01	51·95	32·51	9·50	5·12	0·52	0·80
Standard error of mean								
Sholapuri	0·92	0·10	1·73	2·08	..	..	0·07	0·10
Sundhia	0·42	0·71	1·09	1·98	..	..	0·10	0·10
"t"	0·51	0·94	4·46**	2·03*	..	..	1·08	1·54

* Significant at 5 per cent level

** Significant at 1 per cent level

It can be seen from Table IV that *Sundhia jowar* straw was richer than '*Sholapuri jowar* straw in protein to the extent of 15 per cent, in ether extract, by about 50 per cent and in minerals by about 33 per cent. It was, however, about 20 per cent more fibrous and 15 per cent lower in N. F. E. than the latter. Statistical analysis, however, revealed that only the difference in N. F. E. is highly significant while that in the crude fibre content approaches significance.

In late *kharif* season *Sundhia jowar* is grown in this tract for fodder purposes. It is cut at the prime stage and dried. The dry fodder is locally known as *Batu* or *Kadbi*. The composition of *kadbi* collected from different villages during 1952 and 1953 is given in Table V, and the statistical analysis of the results in Table VI.

TABLE V

Composition of Sundhia jowar kadbi

	(1952) *Kharif*				(1953) *Kharif*			
	Bhalej	Traj	Uttar-sanda	Vadtal	Bhalej	Chakalsi	Napa	Vadtal
Crude protein	6·08	4·83	6·71	4·19	4·96	5·47	7·50	4·98
Ether extract	2·50	1·63	1·95	1·42	1·66	1·25	1·32	1·52
N. F. E.	53·19	58·76	51·80	57·69	58·05	51·86	56·16	56·10
Crude fibre	29·00	25·07	28·50	30·10	25·38	35·20	24·23	29·95
Ash	9·23	9·71	11·04	6·60	9·95	6·22	10·80	7·45
Silica	4·82	5·93	7·12	3·22	5·76	4·00	6·19	3·47
(P_2O_5)	1·01	0·54	0·97	0·69	0·88	0·54	0·97	0·42
(CaO)	0·46	0·80	0·73	0·97	0·66	0·32	0·35	0·42

TABLE VI

Comparison of kharif Sundhia jowar kadbi *of 1952 and 1953*

Year	C. Protein	E. Extract	N.F.E.	C. Fibre	Ash	Silica	P_2O_5	CaO
(4) 1952	5·45	1·87	55·38	28·17	9·14	5·27	0·80	0·74
(4) 1953	5·73	1·44	55·54	28·69	8·60	4·86	0·70	0·44
Standard error of mean								
1952	0·57	0·24	1·80	1·09	..	..	0·10	0·10
1953	0·60	0·10	1·20	2·50	..	..	0·14	0·09
't'	0·34	1·69	0·08	0·19	..	..	0·59	2·14

On comparing the average results for the two years (vide Table VI) it is observed that the fodder of 1953 was poorer in ether extract (by about 25 per cent) and in minerals, particularly in calcium, which was only 60 per cent of the amount in the fodder of the previous year. On statistical treatment it is found, however, that only the difference in calcium approaches significant while that in ether extract is non-significant. The lower calcium content in samples of 1953 may be attributed to heavier rainfall in that year than in 1952. A similar correlation between rainfall and calcium content is reported by Murphy[16] and Cartmill[5]. Ray and Sen[21], however, noted an increase both in calcium and phosphate with abundant rainfall.

SUMMARY

Variation in the young, flowering and straw stages of *Sundhia jowar* (*Andropogon sorghum*) were studied. It was indicated that crude protein and phosphate contents decreased with maturity while crude fibre increased significantly.

A comparison of *jowar* fodder from Bangalore, Bihar, Punjab and Anand (Gujerat) revealed that protein in fodders from Anand and Bangalore decreased with maturity, while in those from Bihar and Punjab, it was somewhat higher in the ripe stage than that in the prime stage. Crude fibre in the fodder from Punjab decreased with growth. The fodder from Anand was found to be richer in minerals than the rest.

Sundhia jowar straw, as compared to *Sholapuri jowar* straw was lower in N. F. E. and more fibrous.

Sundhia jowar kadbi (cut at prime stage and dried) collected from different villages during 1952 and 1953 was analysed. The fodder of 1953 was found poorer than that of 1952, in minerals particularly calcium, probably because of heavier rainfall during that year.

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VARIATIONS IN THE SEED CHARACTERS OF CASHEW (*ANACARDIUM OCCIDENTALE* L.)

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The cashewnut (*Anacardium occidentale* L.) exhibits large variation with regard to its seed characters. Seed propagation which is universally adopted for raising this highly heterozygous, heterogenous, cross pollinated crop is primarily responsible for wide variations in the tree, apple and nut characters. The continuous process of seed multiplication has led to a considerable admixture of types and an assortment of unstandardized material at the processing factories; this has necessitated the employment of highly specialised and costly process of grading the nuts into several categories. The existence of six distinct grades of whole kernels in the market at different prices is an evidence of the vast extent of variation in the raw nuts.

An attempt was made at the Cashewnut Research Station, Mangalore to assess the degree of variation existing in the seed characters with a view to exploring the possibilities of improving the market quality of nuts. The results of the studies are described in this article.

Material and Methods

One hundred seed samples assembled at the Cashewnut Research Station from seven States in the Indian Union and from British East Africa (Nairobi) and Brazil (Rio De Janeiro) formed the material for study. (Appendix I.)

The seed samples were studied with regard to the following characters :

Size. The length and breadth of the seeds were measured in centimeters and the size of each sample expressed in square centimeters.

Weight. The weight of 100 nuts in pounds and the number of nuts making up a pound were determined for each sample.

Volume. The volume of 10 nuts was determined by the displacement of water.

Shelling percentage. The weight of kernels in relation to that of whole nuts expressed as a percentage, was worked out for each sample with regard to unroasted nuts.

Results

From the study of the quantitative characters of 100 seed samples, the following observations were made :

(1) the size of the seeds (length $\times$ breadth) ranges from 4·4 sq. cm. to 12·7 sq.cm. with a mean of 8·4 sq. cm.,

(2) the number of nuts making up a pound ranges from 48 to 212 with an average of 86,

(3) the volume of 10 nuts by displacement of water ranges from 25 c.c. to 115 c.c. with a mean of 75 c.c., and

(4) the shelling percentage or the kernel content expressed as a percentage of the total nut weight in unroasted nuts ranges from 25 to 50 with a mean of 33·3.

The seed samples possessed smooth, bumpy, flat, wrinkled, rough surfaces or a combination of any of these.

The standard deviation, standard error and coefficient of variability with respect to seed size, weight of 100 nuts, volume and shelling percentage of unroasted nuts were worked out. The data are given in Table I.

TABLE I

Data regarding variability with respect to seed size, weight and shelling percentage of cashew nuts

Seed characters	Mean	Standard deviation	Standard error	Co-efficient of variability
Size (L × B in sq. cm.)	8·40	2·87	0·29	34·5
Number of nuts per lb.	85·90	29·40	2·90	34·2
Volume (by displacement of water) c.c.	7·50	2·10	0·21	28·0
Shelling percentage	33·30	6·60	0·66	19·8

It is seen from Table I that a high degree of variation exists in the economic characters and that there is vast scope for selection for a general improvement in the market quality of nuts.

The data were also analysed with a view to determining the correlation between the weight, the size and the shelling percentage of unroasted nuts. The results are given in Table II.

TABLE II

Data regarding correlation between weight, size and shelling percentage

Particulars	Correlation co-efficient	Remarks
Size of seed weight of kernels	0·108	Not significant
Weight of nuts and weight of kernels	0·720	Highly significant

It will be seen from Table II that no significant correlation exists between the nut size and the kernel content, which reveals that the size of the nut is not a reliable index of the kernel content. There is a high degree of correlation between the weight of nuts and weight of kernels ; the heavier the nut, the heavier the kernel.

Discussion

In order to aim at the production of crops of uniform and standard quality it is necessary that the variation is brought down to the minimum. This is possible only through a rigid process of selection of the parent material. Vegetative propagation of such selected progenies should go hand in hand to ensure cent per cent uniformity. Preliminary vegetative propagation trials at the Cashewnut Research Station, Mangalore have shown prospects of success.

Summary

1. Cashew exhibits wide variations in seed characters due to continuous propagation through seed.

2. One hundred seed samples collected from India and abroad were studied with regard to their seed characters.

3. Wide variation was noticed in the economic characters revealing the possibilities of stepping up the market quality of the nuts by selection and vegetative propagation.

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APPENDIX I

Characters of seeds assembled at the Cashewnut Research Station, Mangalore from different sources

Sample No.	Source	Weight		Measurements		Volume of 10 nuts in c.c.	Shelling percentage
		No. of nuts per lb.	Weight of 100 nuts (lb.)	Length in cm.	Breadth in cm.		
1	British East Africa (Nairobi)	62	1·6	3·6	2·8	75	36·3
2	Brazil (Rio De Janiero)	66	1·5	3·8	2·8	90	33·3
3	South Kanara	89	1·1	3·5	2·5	60	28·5
4	do.	67	1·5	3·7	2·7	80	33·3
5	do.	70	1·4	3·0	2·8	75	27·3
6	do.	56	1·8	3·8	3·0	0	35·5
7	do.	60	1·7	3·7	2·9	100	35·5
8	do.	88	1·1	3·3	2·4	65	33·3
9	do.	50	2·0	4·1	3·3	115	42·0
10	do.	48	2·08	4·5	3·4	115	42·0
11	do.	80	1·25	3·4	2·7	65	33·3

APPENDIX I—*contd.*

Sample No.	Source	Weight		Measurements		Volume of 10 nuts in c.c.	Shelling percentage
		No. of nuts per lb.	Weight of 100 nuts (lb.)	Length in cm.	Breadth in cm.		
12	South Kanara	56	1·78	3·7	2·5	75	35·5
13	do.	48	2·08	4·0	3·1	105	42·0
14	do.	64	1·56	3·6	2·9	90	33·3
15	do.	62	1·61	3·6	2·8	85	50·0
16	do.	52	1·94	3·7	3·0	95	35·5
17	do.	48	2·08	4·1	3·1	100	42·0
18	do.	116	0·86	3·1	2·3	60	25·0
19	do.	124	0·71	3·0	2·2	65	25·0
20	do.	58	1·72	3·9	3·1	100	35·5
21	do.	60	1·51	4·2	2·8	85	33·3
22	do.	80	1·25	3·4	2·6	70	33·3
23	do.	78	1·28	3·3	2·7	65	33·3
24	do.	76	1·31	3·3	2·5	55	33·3
25	do.	92	1·08	3·1	2·5	95	33·3
26	do.	66	1·51	3·5	2·6	85	33·5
27	do.	76	1·31	3·5	2·6	95	33·3
28	do.	90	1·11	3·2	2·4	70	33·3
29	do.	66	1·51	3·4	2·6	65	37·5
30	do.	80	1·25	3·1	2·6	75	33·3
31	do.	76	1·31	3·5	2·7	85	33·3
32	do.	80	1·25	3·3	2·4	85	33·3
33	do.	75	1·33	2·8	2·4	25	33·3
34	Malabar	60	1·66	3·7	2·7	60	44·5

APPENDIX I—*contd.*

Sample No.	Source	Weight		Measurements		Volume of 10 nuts in c.c.	Shelling percentage
		No. of nuts per lb.	Weight of 100 nuts (lb.)	Length in cm.	Breadth in cm.		
35	Malabar	90	1·1	2·8	2·2	65	33·3
36	do.	88	1·13	3·6	2·8	50	33·3
37	do.	54	1·78	4·0	3·1	70	44·5
38	do.	96	1·04	3·3	2·2	65	33·3
39	do.	80	1·25	3·1	2·5	60	33·3
40	do.	76	1·31	3·5	2·4	65	33·3
41	do.	76	1·31	3·1	2·5	65	33·3
42	do.	72	1·38	3·5	2·3	70	33·3
43	do.	90	1·1	3·2	2·7	65	33·3
44	do.	104	0·95	3·1	2·5	30	25·0
45	do.	60	1·66	3·4	2·9	45	44·5
46	do.	56	1·78	3·9	3·4	40	44·5
47	do.	60	1·66	3·8	2·9	45	44·5
48	do.	88	1·13	3·2	2·4	50	33·3
49	do.	82	1·21	3·4	2·8	55	28·5
50	do.	72	1·38	3·7	2·5	80	42·8
51	do.	68	1·47	3·7	2·6	85	37·5
52	do.	160	0·62	3·7	2·1	60	25·0
53	do.	212	0·47	2·2	2·0	95	25·0
54	do.	104	0·95	3·2	2·5	80	25·0
55	do.	56	1·78	4·0	3·2	65	43·8
56	do.	120	0·8	2·1	1·8	55	25·0
57	South Arcot	144	0·7	2·5	2·0	75	29·0

APPENDIX I—*concld.*

Sample No.	Source	Weight: No. of nuts per lb.	Weight: Weight of 100 nuts (lb.)	Measurements: Length in cm.	Measurements: Breadth in cm.	Volume of 10 nuts in c.c.	Shelling percentage
58	South Arcot	96	1·0	2·8	2·0	90	33·3
59	Tiruchirapalli	104	1·0	2·4	1·8	85	33·3
60	do.	88	1·1	2·4	2·1	40	33·3
61	do.	112	0·9	2·8	1·9	55	25·0
62	do.	96	1·0	2·7	2·1	45	25·0
63	Chingleput	84	1·2	2·5	2·0	50	42·8
64	do.	86	1·2	3·2	2·3	55	37·5
65	Tanjore	100	1·0	2·7	2·3	60	30·0
66	do.	76	1·3	3·1	2 6	60	37·5
67	Andhra	62	1·6	3·2	2·9	55	42·8
68	do.	64	1·6	3·5	2·5	75	37·5
69	do.	62	1·6	3·3	2·6	50	42·8
70	do.	109	0·9	2·7	2·1	45	25·0
71	do.	72	1·4	2·9	2·4	60	33·3
72	do.	50	2·0	3·4	3·0	55	42·8
73	do.	74	1·4	3·1	2·7	25	33·3
74	do.	90	1·1	3·0	2·2	55	33·3
75	do.	72	1·4	3·3	2·4	55	33·3
76	do.	125	0·8	2·3	2·2	35	25·0
77	do.	100	1·0	4·0	2·7	45	33·3
78	do.	142	0·7	2·9	1·8	35	29·0
79	do.	120	0·8	2·7	1·8	40	29·0
80	do.	52	2·0	4·0	3·7	60	42·0
81	Bombay	156	0·6	3·1	2·7	45	25·0
82	do.	130	0·8	2·8	1·8	80	25·0
83	do.	100	1·0	2·9	2·0	45	33·3
84	do.	100	1·0	2·9	2·0	45	30·0
85	do.	110	0·9	3·1	1·8	45	30·0
86	W. Bengal	84	0·7	3·3	2·5	50	30·0
87	Mysore	120	0·8	2·8	1·8	35	30·0
88	do.	108	0·9	2·7	1·7	85	30·0
89	Travancore-Cochin State	128	0·8	2·7	1·5	35	30·0
90	do.	104	1·0	2·7	1·8	60	37·5
91	do.	124	0·8	2·8	1·7	35	30·0
92	do.	138	0·7	2·7	1·5	35	30·0
93	do.	84	1·2	3·2	2·4	50	33·4
94	do.	90	1·1	3·3	2·2	40	33·3
95	do	76	1·36	3·2	2·3	60	37·8
96	do.	74	1·35	3·4	2·5	60	37·8
97	do.	50	2·0	3·7	2·7	55	42·0
98	Orissa	100	1·0	2·9	2·0	60	33·3
99	T. C. State	72	1·4	1·4	3·3	60	33·3
100	do.	62	1·6	1·6	3·2	55	42·8

MOSAIC DISEASE OF CHILLI (*CAPSICUM FRUTESCENS* L.)

By Ashrafi Jha and S. P. Raychaudhuri, Division of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi

(Received for publication on June 28, 1955)

(With Plate II)

Raychaudhuri and Jha [1954] reported the occurrence of a mosaic disease of chilli (*Capsicum frutescens* L.) at the Indian Agricultural Research Institute, New Delhi, during 1952. Under field conditions, the earliest symptoms were vein-clearing of the younger leaves followed by severe mottling with patches of light and dark green scattered all over the leaf surface. In some cases slight curling, marginal rolling and occasional smalling of leaves were also observed. General stunting of the aerial parts appeared to be a common feature. Few flowers and fruits developed on severely affected plants. Experiments conducted on the causal virus are reported herein.

Material and Methods

The virus was propagated on young seedlings of *Nicotiana tabacum* var. White Burley grown inside the insect-proof greenhouse. Inoculations were done with standard extract which was prepared by crushing the infected leaves of tobacco to which sterilized distilled water was added at the rate of 1 c.c. per gram of leaf material. Throughout the course of these experiments, young actively growing plants of strain N. P. 46A of chilli and tobacco var. White Burley were used.

Transmission of the Disease

(*a*) *By sap inoculation.* Severely affected leaves of tobacco were crushed to a fine pulp and the juice extracted out. This extract was then squeezed through absorbent sterilized cotton. The sap thus obtained was used in all inoculation experiments. Finely powdered carborundum was used as an abrasive. Inoculations were made on 53 spp. and the varieties of plants belonging to 11 families. The disease was transmitted to *Capsicum frutescens* L., *Nicotiana tabacum* L. including var. White Burley (Plate II, Fig. 1), *Nicotiana* selections 78 and 78A (obtained from Botany Division), *N. glutinosa* L, (Plate II, Fig. 2), *Solanum nigrum* L., *Petunia hydrida* Vilm., *Cucumis melo* L. var. *utilissimus*, *C. sativus* L., and *Carthamus*

tinctorius L. *Solanum tuberosum* L. var. President and Craigs' Defiance as well as *Datura stramonium* L. carried the virus symptomlessly. The symptoms which developed in host plants that were infected are given in Table I.

TABLE I

Characteristic symptoms of chilli mosaic on various host plants

Family	Host species	Characteristic symptoms
Solanaceae	*Capsicum frutescens*	Vein clearing followed by systematic mottling and reduction in leaf size. Leaves occasionally malformed
	Nicotiana tabacum	Vein clearing followed by mild mottling
	N. tabacum var. White Burley	Mottling starting from tips and margins of the new leaves
	N. glutinosa	Severe mosaic mottling and malformation of leaves which were frequently reduced in size
	Nicotiana selections 78 and 78A	Mosaic mottling followed by slight curling of leaf margin
	Solanum nigrum	Mild mosaic mottling on affected leaves
	Petunia hybrida	Mosaic symptoms starting from tip of leaf and finally spreading to the whole leaf
Cucurbitaceae	*Cucumis sativus*	Vein clearing followed by greenish yellow mottling
	Cucumis melo var. *utilissimus*	Interveinal areas showed typical moasic symptoms
Compositae	*Carthamus tinctorius*	Light and dark green patches scattered over infected leaves

The following plant species were inoculated with the virus but not infected :

Solanaceæ—*Solanum tuberosum* L. var. Up-to-date, Arran victory 41956, *S. nodiflorum* Jacq., *S. melongena* L., *Lycopersicon esculentum* Mill. ; Leguminosae—*Cajanus cajan* (L.) Millsp., *Dolichos lablab* L., *Crotalaria juncea* L., *Crotalaria mucro-*

FIG. (1) Symptoms on *Nicotiana tabacum* var. White Burley

FIG. (2) Symptoms on *Nicotiana glutinosa*

FIG. (3) Transmission of the disease by ***Aphis Gossypii*** on chilli

nata Desv., '*Pisum sativum* L., *Trifolium alexandrium* L., *Cicer arientinum* L. *Vicia faba* L., *Cyamopsis tetragonoloba* (L.) Taub., *Medicago sativa* L. ; Cruciferæ —*Brassica oleracea* L. var. *botrytis*. *B. oleracea* L. var. *capitata*, *B. caulorapa* Pasq., *B. campestris* L. var. *toria*., *B. rapa* L., *Raphanus sativus* L. ; Rutaceæ—*Citrus limon* Dwarf. ; Malvaceæ—*Gossypium arboreum* L., *Hibiscus rosa-sinensis* L. ; Cucurbitaceæ—*Lagenaria siceraria* Standl., *Cucumis melo* L., *Citrullus vulgaris* Schrad., *C. vulgaris* var. *fistulosus*, *Momordica charantia* L. ; Compositæ—*Zinnia elegans* Jacq., *Callistephus chinensis* Nees., *Calendula officinalis* L., *Tagetes erecta* L., *Chrysanthemum morifolium* Ramat.; Myrtaceæ—*Psidium guajava* L.; Umbelliferæ—*Daucus carota* L.; Chenopodiaceæ—*Beta vulgaris* L. ; and Apocynaceæ—Vinca *rosea* L.

(*b*) *Transmission of the disease by insects*. After making a survey of the insects occurring on the mosaic affected chilli plants at the I.A.R.I. during November, 1952 to February, 1953, it was found that *Aphis gossypii* Glover was mostly feeding on the diseased plants while white flies (*Bemisia tabaci* Gen.) were occasionally met with. Hence, transmission tests were carried out with these two species of insects. The insects collected from different sources were tested on healthy chilli, tobacco and tomato plants to determine if they were carrying any of the common viruses known to occur in Delhi. All these preliminary tests proved that the white flies and *Aphis gossypii* were free from viruses which are known to infect these test plants.

The white flies after feeding on severely affected chilli plants for 48 hours were transferred in the same microcages to healthy chilli, tobacco and tomato test plants on which they were allowed to feed for seven days. In none of the 60 test plants, the disease was transmitted during a period of two months showing thereby that the white flies are not the vector of the chilli mosaic virus.

Ten to 12 adults of *A. gossypii* caged in cellophane bags and previously allowed to feed for 48 hours on diseased chilli plants, were transferred to healthy test plants of chilli, tobacco and tomato and allowed to feed for 7 to 10 days. Out of 61 chilli plants tested, only 9 came down with the typical disease symptoms after four to six weeks (Plate II, Fig. 3).

(*c*) *Attempts to transmit the disease by seed*. Martin [1930] reported transmission of mosaic of pepper by seed while Doolittle and Walker [1925] observed that the virus was not transmissible by seed. In an attempt to find out if the virus under study was transmitted by seed, 114 seedlings were raised from seeds collected from severely affected chilli plants. No disease symptoms were observed on these plants, which indicates that the virus causing mosaic of chilli in Delhi is not seed transmissible.

Properties of the Virus

(a) *Thermal death point*

Equal quantities of the standard extract in test tubes of uniform size and thickness were exposed to 40°C., 50°C., 60°C., 65°C., 70°C., 75°C., 80°C., 85°C., 90°C., and 95°C. in a water bath for 10 minutes. These

were then plunged in cold water. Another tube was maintained as unheated check. The experiment was repeated thrice, and the heated samples were used for inoculating young healthy tobacco and chilli plants. The virus tolerated exposure to 55°C. for 10 minutes, but was inactivated at 60°C. after exposure for the same period.

(b) *Dilution end-point*

The undiluted crude juice was diluted with distilled water to various dilutions and the infectivity of these samples was tested on young healthy tobacco and chilli plants. Two experiments were done which indicated that the dilution end-point of the virus lies between 1 : 25,000 to 1 : 30,000.

(c) *Longevity in vitro*

Standard extracts stored at room temperature (15°-33°C.) were used for inoculating healthy tobacco and chilli plants at regular intervals. The virus was found to retain its infectivity after 15 days at room temperature but was inactivated after 22 days.

(d) *Effect of various chemicals on the infectivity of the virus*

Standard extracts of the virus centrifuged at 3,500 r.p.m. in an angle centrifuge of the 'Wifug' type for 20 minutes, were treated with different chemicals to study their effect on the infectivity of the virus. Immediate inoculations were made followed by subsequent inoculations after 4 hours and 24 hours. The virus lost its infectivity immediately after treatment with 50 per cent nicotine sulphate, and 1 per cent silver nitrate, while 50 per cent ethyl alcohol after treatment for 4 hours rendered the virus innocuous. Also, 0·5 per cent silver nitrate and 0·25 per cent carbolic acid inactivated the virus after treatment for 24 hours.

(e) *Effect of ultra-violet irradiation on the infectivity of the virus*

Following the technique employed by Raychaudhuri, Lal and Vasudeva [1950], centrifuged standard extracts of the virus as well as samples diluted to 1 : 10 and 1 : 100 were used for inoculations after exposure to ultra-violet light, the source of which was an Alpine Sunlamp, Model IX. The materials were exposed for varying periods at a distance of 24 inches from the arc tube. Unexposed check was maintained in each case. These tests indicated that the virus withstood exposure to ultra-violet irradiation for four hours (342·72 m.u.d.) while it lost its infectivity after exposure for a period of six hours (514·08 m.u.d.).

Discussion

Chilli has been reported to be a host plant of a number of virus diseases. Blodgett [1927] recovered potato virus X from naturally infected peppers, which also proved to be an excellent test plant for the virus [David and Stormer, 1941]. Pepper has been reported to be naturally affected by the tobacco mosaic [Kendrick *et al.*,

1951 ; Palm, 1923], the cucumber mosaic [Chamberlain, 1939 ; Doolittle and Zaumeyer, 1953] the tobacco etch [Boyd, 1948 ; McKeen, 1954], tomato spotted-wilt [Kendrick, *et al.*, 1951], the alfalfa mosaic viruses [Kovacevski, 1942] and a strain of alfalfa mosaic virus, *Marmor medicaginis* var. *capsici* Holmes [Berkeley, 1947]. Chilli has also been experimentally infected by the southern sunnhemp mosaic virus [Capoor, 1950]. In addition, a mosaic disease of peppers has been described from Puerto Rico [Roque and Adsuar, 1941] and a pepper vein-banding virus from Trinidad [Dale, 1954].

The chilli mosaic described herein differs from the diseases mentioned above either in its physical properties, host plants, or insect transmission. It also differs from the graft-transmitted chilli mosaic studied by Lal [1949] and the mosaic disease of chilli reported to be transmitted by thrips in the Bombay State [Uppa, 1929].

Summary

A mosaic disease of chilli, *Capsicum frutescens* L. which is of common occurrence in Delhi, is described.

In addition to chilli, the disease is transmissible by sap inoculation to *Nicotiana tabacum* L., *N. tabacum* var. White Burley, tobacco selections 78 and 78A, *N. glutinosa* L., *Solanum nigrum* L., *Petunia hybrida* Vilm., *Cucumis sativus* L., *C. melo* L. var. *utilissimus* and *Carthamus tinctorius* L. Potato vars. President and Craigs' Defiance as also *Datura stramonium* L. carry the disease symptomlessly. The disease is not carried through seed.

Aphis gossypii Glover has been found to transmit the virus in about 15 per cent plants.

The virus is inactivated when exposed to 60°C. for 10 minutes, and at a dilution of 1 in 30,000.

Acknowledgments

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REVIEW

THE FORESTER'S COMPANION

By N. D. G. James ; Published by Basil Blackwell, Oxford

IN just over 300 pages, the author in this book has condensed all the knowledge and information regarding day to day forestry which a working forester, a forest manager or a forest owner (particularly in England and Wales) may require in a handy form. All the major branches of forestry, viz. policy, silviculture, management, protection and utilisation are presented well in an abridged form. Information regarding amenity forestry, e.g. shelter belts, arboriculture and tree planting is also included. It also contains a large amount of miscellaneous informations which are necessary for a field or practical forester but are not available in text books. Particulars regarding Forestry Commission, societies concerned with forestry or trees, Forestry Departments and Organisation, botanic gardens, arboreta and forest parks and books and periodicals on forestry are very valuable for practising foresters in England and Wales.

It is a useful pocket book which (specially in the U.K.) should form an essential part of every forest worker's equipment. The book is equally useful to land owners land agents, forest officers and forestry students. Clarity, brevity and tabulation of information in order to avoid loss of necessary details have largely contributed to the practical value of the book. The small size of the book is convenient for carrying it to the field.

The author and the Royal Forestry Society of England and Wales deserve to be congratulated on this comprehensive publication on practical forestry. (C.A.R.B.)

SOIL AND WATER CONSERVATION ENGINEERING

By R. K. Fravert, G. O. Scwab *et. al.*, Agricultural Engineering Series : Ferguson Foundation. John Wiley & Sons, New York, 1955

THIS book is the latest American publication in the field of land development, which consists of the fields of farm drainage, irrigation, land and jungle clearing and soil conservation. It deals with the engineering principles of soil and water conservation. Although it is intended for engineers in the field of agriculture or irrigation, it is a good reference book for soil scientists and agronomists.

The authors have collected necessary information from several sources in the U. S. A. such as the Soil Conservation Service, Agricultural Experiment Stations, Bureau of Reclamation, etc. and have presented it in a simple manner. As usual with many American text books, derivation of formulae from fundamentals is avoided and even those who have not much knowledge of fluid mechanics or soil physics find it simple to understand the facts. However, a basic knowledge of surveying and soils is assumed.

As the information is collected from U. S. sources, the introductory chapter dealing with the extent and scope of soil erosion control, drainage and flood control, irrigation, etc. refers to present conditions in that country. So also is Appendix 'A', which refers to rainfall characteristics in the U. S. A.

Chapter 2 refers to precipitation and method of measurement of rainfall and explains the rainfall distribution in the U. S. A. Chapter 3 deals with evaporation and transpiration. It is explained that by maintaining high infiltration rates, erosion may be reduced and a measure of gully and flood control provided. Chapter 4 refers to methods of predicting, calculating and also of measuring run-off from water sheds for purposes of surface drainage. Fundamentals of soil physics are discussed in chapter 5 which includes soil structure, texture, soil moisture and its movement, porosity, permeability, etc. The above mentioned five chapters are preliminary to the understanding of soil erosion and its control, drainage, irrigation, etc.

The types of erosion due to wind and water are included in Chapter 6, which includes methods for estimating soil losses and loss of soil fertility. Control of wind erosion by vegetative methods, cropping systems and tillage practices are explained in Chapter 7. Methods adopted in the U. S. A. for soil conservation such as contouring, strip cropping and other tillage practices are dealt with in Chapter 8. Methods and implements used for sub-surface tillage are also of interest to Indian soil scientists, agricultural engineers and agronomists. The implements used and recommended are similar to the *Bakhar* (of central India) or *Guntaka* (of Madras) or *Ḳunte* (of Carnatic). This implement is used in many parts of India, where black cotton soils prevail. The use of this implement was known in 5th century A. D. in India, is substantiated by the exhibits from a museum in Sanchi (Bhopal State). This implement is used in India for water conservation, specially retention of soil moisture in areas of scanty rainfall and also as an effective implement for weed eradication. Principles of design and construction of drainage channels and their outlets from farms have also been explained.

Chapter 12 deals with earthen embankments and reservoirs. This chapter should be of interest in the southern States of India, where there is a large number of water tanks (ponds or reservoirs) with earthen embankments for irrigation. Construction, compaction and methods of maintenance of earthen embankments are also explained. Methods suggested here for watering facilities for livestocks from ponds and reservoirs do not seem to be known in India. Types of floods,

methods of flood control and routing of floods are explained in Chapter 13. Surface drainage by open ditches, and methods and equipment for construction of open ditches are included in Chapters 14 and 15. Principles of tile drainages, their design, construction and maintenance are explained in Chapters 16, 17 and 18. Chapters 19 and 20 refer to pumping for drainage and irrigation and also the use of spray irrigation or sprinkler irrigation which is becoming popular in the U. S. A. Land clearing equipment and methods are described in Chapter 21. Mechanical and chemical methods of wood and bush eradication are mentioned in this chapter. The last chapter refers to legal aspects of soil and water conservation as applicable to the U. S. A.

The following statements appearing on page 299 are of special interest. Discussing alternate methods for ditch construction, it states "It is generally more economical and practical to use machinery than to use explosives" if this is true in the U. S. A. perhaps it is much more true in India, as cost of machinery in India is higher than in U. S. A. The use of explosives in agriculture or irrigation in India is not so generally known. Again on the same page, the authors say "Since costs vary widely from section to section and from year to year, specific data is of little value". In estimating costs of either land reclamation, jungle clearing or tractor work on the farm, costs from one place to another or from one time to another cannot be strictly compared. Text books or other books of reference should indicate only methods of calculating costs and not give actual costs in any particular areas.

This text book will be of use for the agricultural officers in the river valley projects and in other parts of India, where soil conservation is being taken up during the Second Five-Year Plan. The book is extremely useful and interesting to students and professionals in agricultural engineering, soils and agronomy.

At the end of each chapter there is a list of references from published literature in the U. S. A. The book has a number of illustrations and sketches, which clarify the statements in the body of the text. (R.V.M.)

The Editorial Board in its work of examining papers received for publication is assisted in an honorary capacity by a large number of scientists working in various parts of India.

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Article intended for *The Indian Journal of Agricultural Science* should be accompanied by short popular abstracts of about 330 words each.

In the case of botanical aud zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

Reference to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the authors' name, followed by the year of publication enclosed in brackets ; when the author's name occurs in the text, the year of publication only need be given in brackets. If the reference is made to several articles published by one author in a single year these should be numbered in sequence and the number quoted after year both in the text and the collected references.

If a paper has not been seen in original it is safe to state ' original not seen '. Sources of information should be specifically acknowledged.

As the *format* of the journal has been standardized, the size adopted being crown-quarto (about $7\frac{1}{2}$ in. $\times$ $9\frac{5}{8}$ in. cut) no text figure, when printed should exceed $4\frac{1}{2}$ in. $\times$ 5 in. Figures for plates should be so planned as to fill a crown quarto page, the maximum space available for figures being $5\frac{1}{2}$ in. $\times$ 8 in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Indian Council of Agricultural Research, New Delhi.

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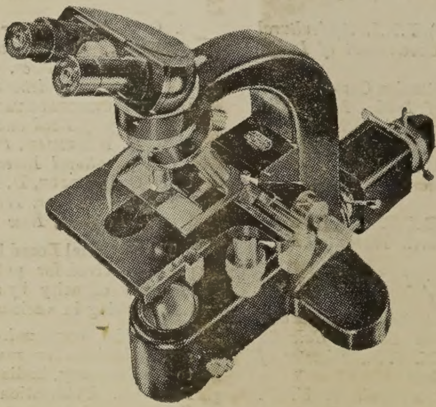

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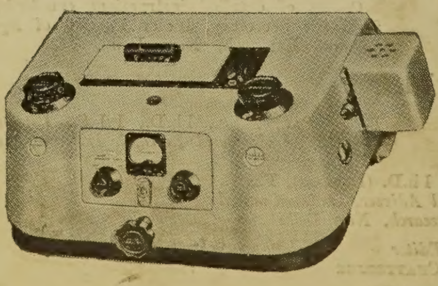

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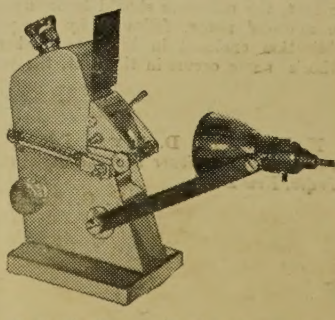

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